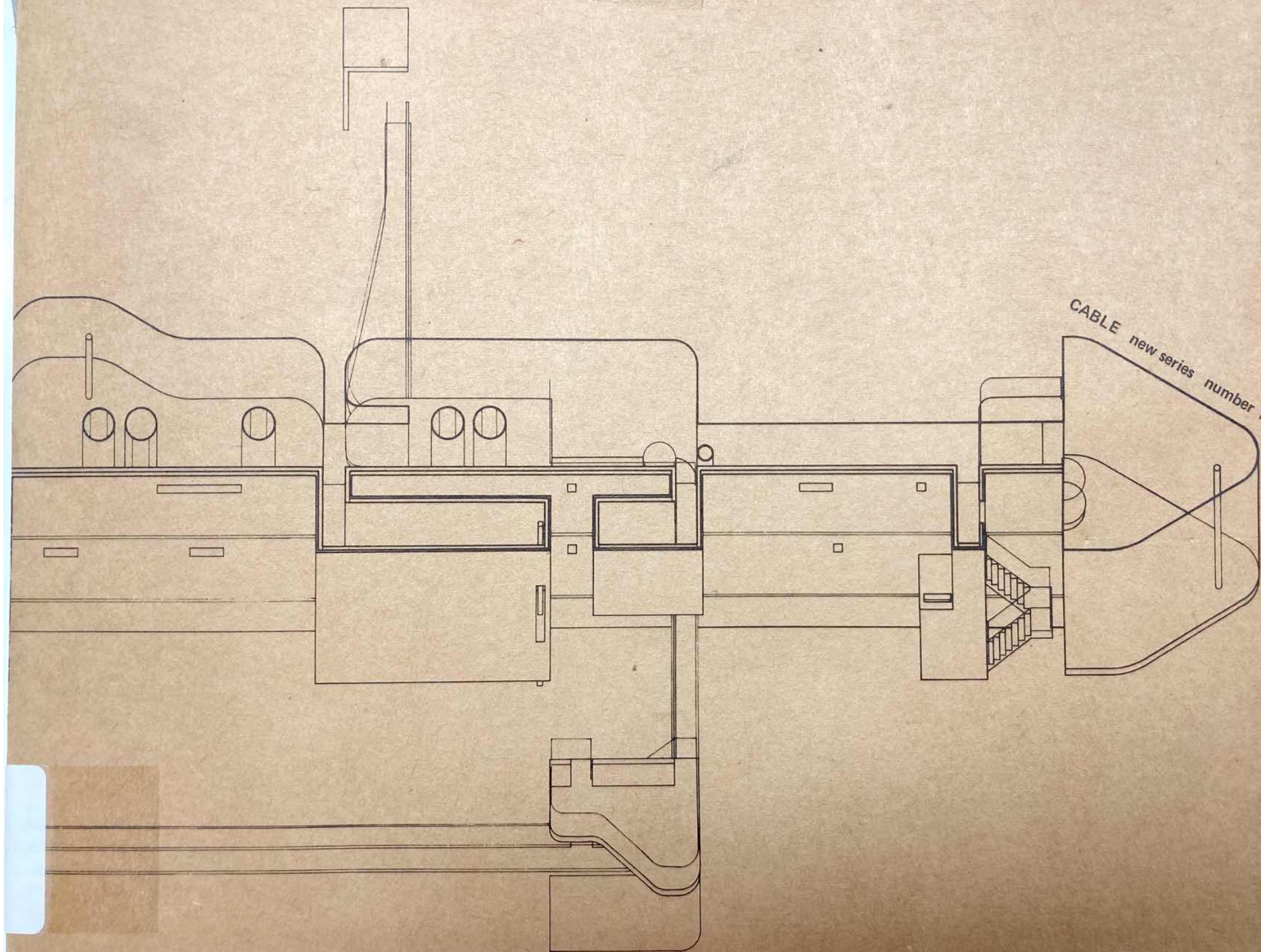


CABLE new series number 1 1969



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NEW PREXY

The late Richard F. Humphreys was an uncommon man — intelligent, talented and purposeful, he was not given to the waste of time, words or money. This article by Geoffrey Hellman will enable those who did not know him to obtain an informing glimpse of the man.

PHOTOGRAPHS

The generations collided once more in 1969, albeit perhaps more violently than ever before. The camera is witness not to fact, but to the act.

DESIGN OF A LIMITED-VOCABULARY SPEECH RECOGNITION SYSTEM.

We are told that modern man finds it increasingly difficult to relate to his fellows. Well, cheer up. David Durst and Michael Lefkowitz have designed a device that will enable us to talk to our computers. Of course they won't talk back — but is that bad? One hitch — you have to be able to count to nine.

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With this house Paul Amatuzzo won the 1969 Paris Prize of the National Institute for Architectural Education. Studio critics were Professors John Hejduk, Robert Slutzky and Peter Bruder. A statement concerning the origins of this Thesis problem follows.

PAINTINGS

Roth's paintings are on glass. Brandes' is on canvas.

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If not the **only** then certainly the **most** intelligent and perceptive critique to date concerning Le Corbusier's Carpenter Center for the Visual Arts at Harvard University.

RUBBINGS

Seven Manhattan manhole covers are given an archeophilic rendering by Lynn Tiefenbacher.

COMMENCEMENT

Twenty-nine certificates, two hundred twenty-three undergraduate degrees and ten graduate degrees were conferred at the one hundred and tenth annual commencement. The recipients are listed herein.

ROTATION STUDIES

The rotation of figures about fixed or moving points has interested Tina Rose for some time now. A few of her studies are reproduced here.

PHOTOGRAPHS

Despite the turmoil, God, country and Peter Cooper are still in evidence.

NEW PREXY

GEOFFREY HELLMAN
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Our old institutional friend Cooper Union has just installed a new president, Dr. Richard F. Humphreys — its seventh in a hundred years — and we've had an institutional chat with him in his office, facing the Bowery. He is a slender, mischievous-looking fifty-year-old bachelor physicist and amateur musician with a turned up nose, a wry expression, a deep voice, and an informal manner; he was born in Greenville, Ohio; he is a DePauw University B.A., a Syracuse University M.A., a Yale Ph.D., and an erstwhile Syracuse and Yale faculty member; and at the time he got the call from C.U. he was vice-president of the Armour Research Foundation of the Illinois Institute of Technology, in Chicago.

"My career is fairly easily epitomized," he said, throwing one leg over an arm of his chair. "The first half of it was spent in teaching and the second half in research administration. Cooper Union picked up my name in two or three spots a little over a year ago — it had been looking for a president since Dr. Edwin S. Burdell resigned, in 1960 — and I came here last June. My installation, which took place on February 12th, was timed so as to occur on the hundred-and-seventy-first anniversary of the birth of Peter Cooper, the founder. I spent my first three months here doing my homework. This is a fascinating place, but there are a few problems. We have two undergraduate schools — Engineering, and Art and Architecture — representing disciplines that are not mixed. And we have two other educational divisions — the Museum for the Arts of Decoration, and the Division of Adult Education — that are relatively unrelated either to the undergraduate schools or to each other. I've accumulated several soapbox speeches: Can we, a small college, afford to operate in so many different areas of education? How long should an engineering education be? We give a bachelor's degree for a four-year course, but professionals often find that this isn't enough, and go elsewhere for higher degrees. How about our night schools of engineering, art, and architecture? The engineering school requires eight years for a degree; it takes four years to get a certificate in art or architecture. These schools are no longer filling the role they used to fill. Because of the economic state of our society, which now provides so many other free schools and so many foundation scholarships, it's easier for a high-school graduate to go on and get his education without working all day and studying at night. And we have a financial problem. For the first time, we are facing a deficit, and it will increase. For seventy-five years, our endowment easily met our needs, but since the mid-thirties, with educational costs rising so much more rapidly than endowment income, we've just been squeezing by. The image of Cooper Union has to be changed. We need increasing alumni support, and we don't get enough industrial support. It's our own fault; we haven't gone after it."

Dr. Humphreys handed us a copy of his first President's Report, and in it we read that Cooper Union's four outstanding assets are "the quality of our student body; the loyalty of faculty and staff members . . . ; the high reputation Cooper Union enjoys; and the relatively untapped asset of flexibility," and that

I [Dr.H.] am not impressed by the argument that we are a "subway college" and cannot influence students' after-class activities. . . . Though there are disadvantages in urban living such a long way from good skiing, though elm and ivy are in short supply at Cooper Square, there are advantages, too.

Our atmosphere is never poisoned by such anti-intellectual smog as the two-day football carnivals which descend on some of the more picturesque campuses. . . . A stroll in any direction from Astor Place brings our students to little galleries and studios where some of the best and worst art of our time is being created or displayed — and our students will profit from studying both.

We invited this enlightened chauvinist to tell us something about himself, and he said, "My father died when I was five. He'd been a successful building contractor in Greenville, Ohio — fancy roofs, elaborate tile — but his health failed and he was told to go live on a farm, so we removed to one near Martinsville, in central Indiana. After his death, my mother became the victim of a bank foreclosure, and I eventually got a four-year scholarship at DePauw. Summers, I ran a dance band, worked for an undertaker, Simonized cars at a filling station, and sold vacuum cleaners." In 1939 Humphreys went to Syracuse to teach physics. From 1940 to 1949, he taught it at Yale; he became acting director of its Sloane Physics Laboratory in 1941. During the war, he also served as a consultant physicist to the New Haven Clock Company, working on submarine-detection devices, and spent a year's leave of absence from Yale on similar sonar work for the Bureau of Ships, in Washington. After Yale came the Armour job, in the course of which he got the Foundation the first nuclear reactor available for private industrial research. "It was a wrench leaving Chicago," he told us. "I loved the place, I had many friends there, and I had an electronic organ that was so big I couldn't bring it along to New York. It had two hundred and sixty-five vacuum tubes and about fifteen miles of wire. I gave it to a church. I got my musical start in a church — the First Methodist of Martinsville, which gave me practice privileges when I was thirteen. My mother, who is still living in Indiana, used to drag us three kids there (I have a brother in Washington; our sister died), and one Sunday morning I woke up and saw this interesting object — the pipe organ. It was an old tracker-action model, which means that it was operated mechanically, by levers. I practiced on it for years. With the help of faculty friends, I've built an electronic organ in a farmhouse that Cooper Union allows its president to use, at Green Camp, in the Ramapo Mountains, which we think of as our Ramapo campus, and I have another organ, a Baldwin, in my apartment, on Tenth Street. I play — or play at — mostly classical things; Bach is my favorite. Playing the organ is a wonderful reliever of tension. You go home in the afternoon just weary down to the ground, and sit at the organ and relax." Weekends, Humphreys relaxes at the farmhouse. "The sky is gorgeous out there," he said. "At first, I had trouble realizing that I was within forty miles of millions of people."

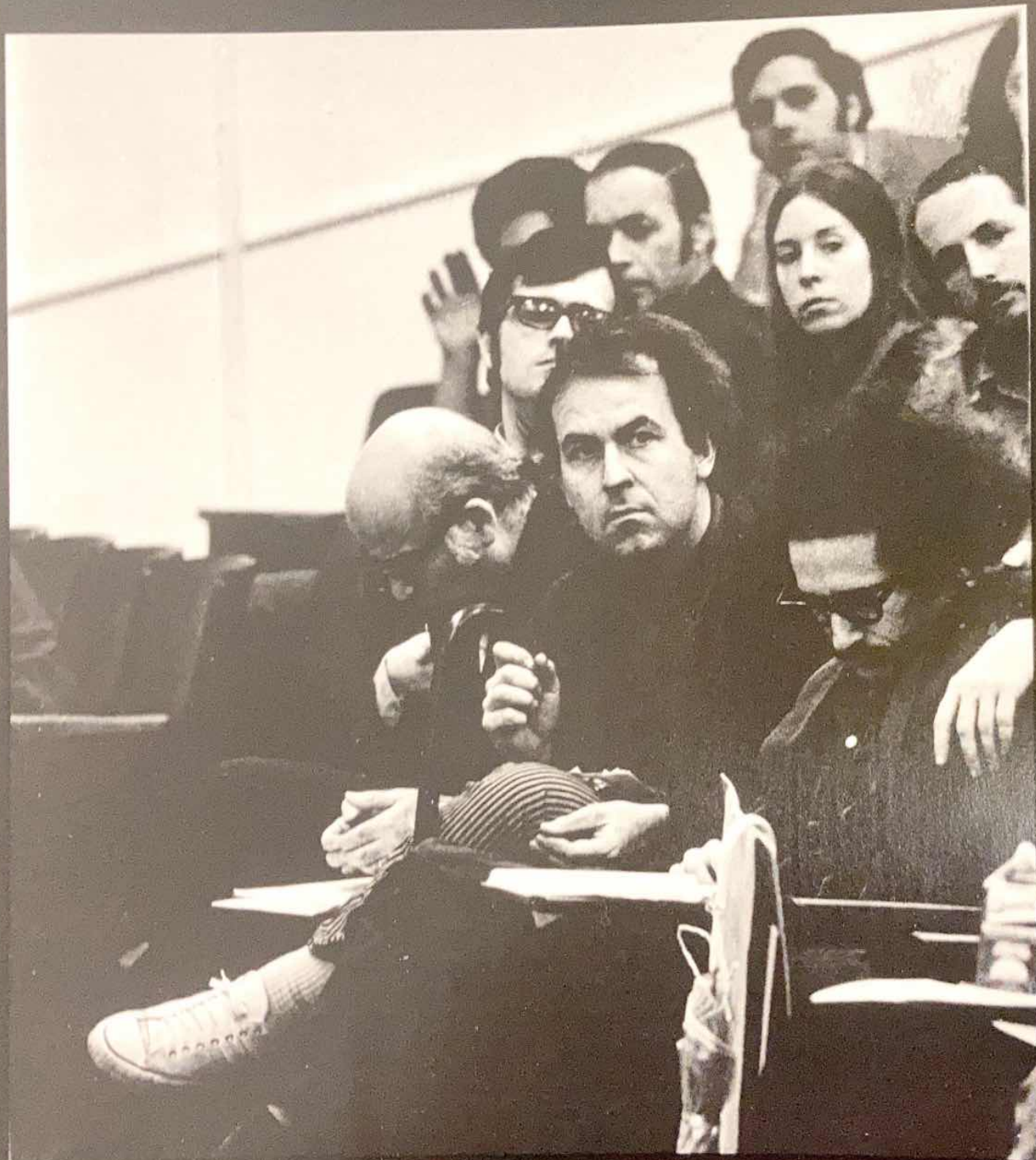
We rose to leave, and the seventh president of Cooper Union walked over to a sofa and showed us the mace that Irving S. Olds, chairman of the college's trustees, handed him at his installation ceremony. "Sterling silver," he said. "It was made specially for the occasion by Robert Yorke Goodden, of the Royal College of Art, in London. The mace was originally used as a weapon to preserve academic authority, but now it's just a symbol of it."

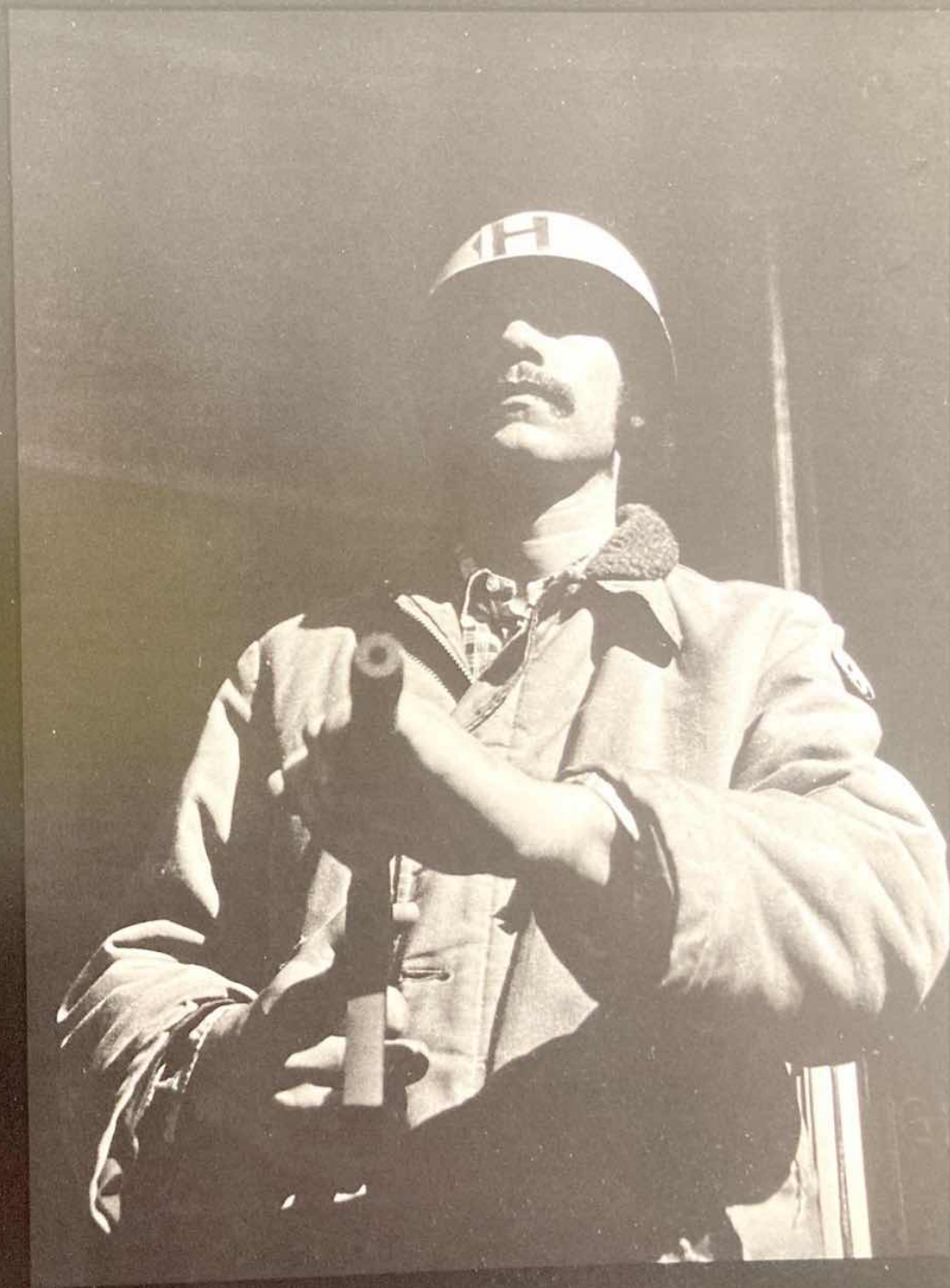
John C. Clark













DESIGN OF A LIMITED-VOCABULARY SPEECH RECOGNITION SYSTEM

DAVID I. DURST
MICHAEL LEFKOWITZ

This report discusses the design and fabrication of an automatic speech recognition system capable of recognizing and displaying the spoken digits zero through nine. A new speech perception theory — the Single Equivalent Formant (SEF) principle — is utilized in this design.

One part of the system consists of analog circuitry which extracts the SEF frequency and two other basic parameters of the speech waveform. Digital circuitry is then used to analyze these parameters and perform the logic required for word recognition.

The device was found to be able to recognize with satisfactory consistency the ten digits as spoken by five persons. From this it was concluded that the Single Equivalent Formant concept is practical for the design of a limited vocabulary speech recognizer.

INTRODUCTION

As our technological society becomes more and more computer oriented, the need for simplicity in the preparation of input information to computers increases. Oral input, if feasible, would be the simplest way. In order to achieve this end, reliable speech recognizers must be developed. In addition to computer-oriented applications, speech recognition has many other future possibilities. Orally operated telephones and elevators come to mind. Other devices could be voice operated teletype machines, remote control devices, and 'hands free' pilot controls. For example, a limited vocabulary voice recognizer could be used to change a pilot's radio channels as he flies cross-country without the need for him to take his hands off the stick.

There is a great need for speech recognition devices but, at the same time, a lack of technological development. The main difficulty in designing a speech recognition system is in making it independent of voice differences among speakers. In recent years, a large part of the research on this topic has been done at Philco Ford and at Bell Telephone Laboratories.

At Bell Telephone, Dudley and Balashek¹ have experimented on a voice recognition system using very narrow band-pass filters. At Philco Ford, Dr. Louis R. Focht² has developed the Single Equivalent Formant (SEF) concept upon which the design of this system is based. He has also developed the SEF parameter extractors used in this study. The single equivalent formant parameters are practically independent of the speaker, while the narrow band-pass filters mentioned above require adjustment among speakers. In addition to this important advantage, a speech recognition system based on the SEF concept is simpler and more economical because less logic is required. The particular recognition scheme and associated logic circuitry

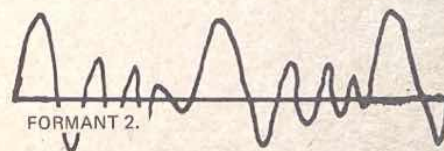
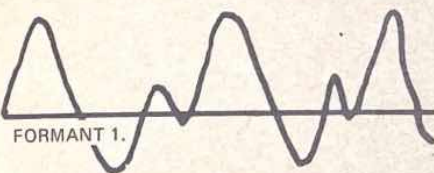
described in this report were designed and developed by the authors.

Much of the theoretical background on human speech perception essential to understanding the speech recognition problem was acquired from various publications of Haskins Laboratories. Using this background and the Single Equivalent Formant concept, the limited vocabulary (ten digits) speech recognition system described here was designed and fabricated.

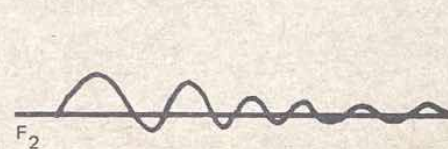
THE CONCEPTUAL SYSTEM

A formant is an individual band of high concentrations of spectral density caused by resonances in the vocal cavities. A spoken utterance usually contains three or more of these formants. The frequencies of the three formants, their amplitudes, and voicing information are necessary for accurate word recognition. However, in order to simplify the recognition logic, it is necessary to reduce the number of parameters considered. This is where the concept of the SEF is introduced. Using this concept, six of the above parameters can be reduced to two equivalent parameters — the single equivalent formant frequency and its amplitude. These two, in addition to a voicing decision, constitute all the information required for speech recognition. The extraction of a single equivalent formant is based upon the characteristics of the speech waveform and the fact that when a person hears a multi-formant sound, his attention focuses on only the dominant one. The presence of other formants (called recessives) serves only to modify the perceived sound slightly from that of the dominant formant. This is analogous to the hue shift that occurs when the eye is presented with two different unmixed colors. The formation of a three formant speech sound is shown in Figure 1a. Each glottal or noise excitation produced by the vocal organs acts as a driving function which initiates a complex ringing phenomenon in the oral cavities. The ringing frequencies of these clamped sinusoids are the formant frequencies whose energies add to produce the complex speech waves. The relative formant amplitudes determine how these waveforms add. Figures 1b, 1c, and 1d show this in detail. The third formant (highest frequency) can usually be neglected in comparison to the first two. When the first formant is larger in amplitude than the second, the period of the first major oscillation of the complex speech wave is approximately equal to that of the first formant. The same holds true when the second formant is larger in amplitude. The period of the first major oscillation of the complex wave is approximately the same as that of the second formant. When the two formants are equal in amplitude, the resultant period of the first oscillation of the speech wave is equal to the average of the

(a)

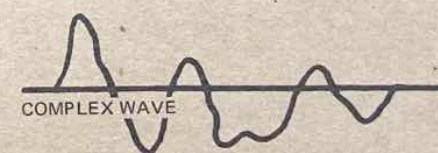
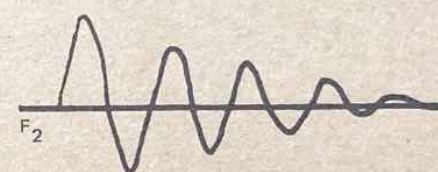


(b)

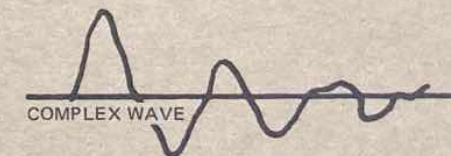
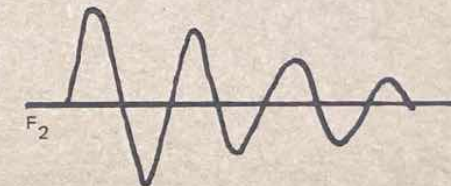
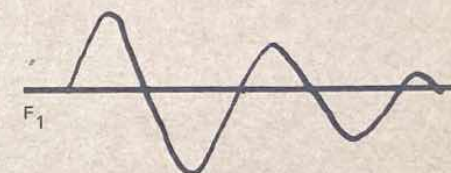
 $F_1 \quad F_2$ 

PERIOD OF LARGEST OSCILLATION OF COM-
PLEX WAVE F_1 PERIOD.

(c)

 $F_2 \quad F_1$ PERIOD OF LARGEST OSCILLATION
PERIOD.

(d)

$$F_1 \quad F_2$$


F_2 PERIOD OF LARGEST OSCILLATION
 $F_1 F_2 / 2$ PERIOD.

two formant periods.

It was shown by Focht³ that for the back vowels, such as u in 'tool' and ɔ in 'talk', the first formant is dominant and nearly equal in frequency and amplitude to the SEF. For the front vowels, such as E in 'ten' and I in 'tip', it is the second formant which is dominant and nearly equal in frequency and amplitude to the SEF. The first two formants for the central vowels, such as a in 'tar', are nearly equal in amplitude and the SEF frequency is approximately the average of the first and second formant frequencies. The third formant in all cases has little or no effect on the SEF. All this is shown in Figure 2, taken from the above reference.

It was concluded that the period of the first major excursion of the complex speech waveform at each glottal excitation provides a measure of the single equivalent formant frequency. Therefore, in order to extract the SEF frequency from the complex speech waveform, the period of the first major oscillation must be measured.

In addition to the SEF frequency, two other parameters are considered. These are the derivative of the logarithm of the SEF amplitude and voicing. The voicing decision depends on whether a sound is produced by vibrations of the vocal cords (voiced) or by air passing through a constriction of the teeth or mouth (unvoiced). The purpose of using the derivative of the amplitude rather than the actual amplitude is to minimize differences between speakers, since the rate of change of amplitude within a word is relatively uniform from speaker to speaker.

The analog waveforms of each parameter are recorded on the Visicorder⁴. Design data for the recognition logic are obtained through a visual analysis of recordings of various speakers and a recognition scheme is developed. It was determined that up to four pertinent points have to be sampled in order to recognize each individual digit. The recognition logic compares the parameter values at these points with a set of acceptable levels which are determined in advance to arise at the corresponding segments of the word. It also checks the time sequence of the segments for every digit.

THE PHYSICAL SYSTEM

a - parameter extractors

SEF EXTRACTOR

The single equivalent formant is extracted from the complex speech waveform by measuring the time between the glottal impulse and the next following zero axis crossing. Each time interval is converted into an analog voltage. The resulting waveform, representing the SEF frequency as a function of time throughout the spoken word, is band limited to 25 Hz and used as the primary parameter in the recognition logic. The SEF extractor is shown

FIGURE 2. CORRELATION OF THE SINGLE EQUIVALENT FORMANT AND HUMAN-VOWEL FORMANT LOCATIONS.

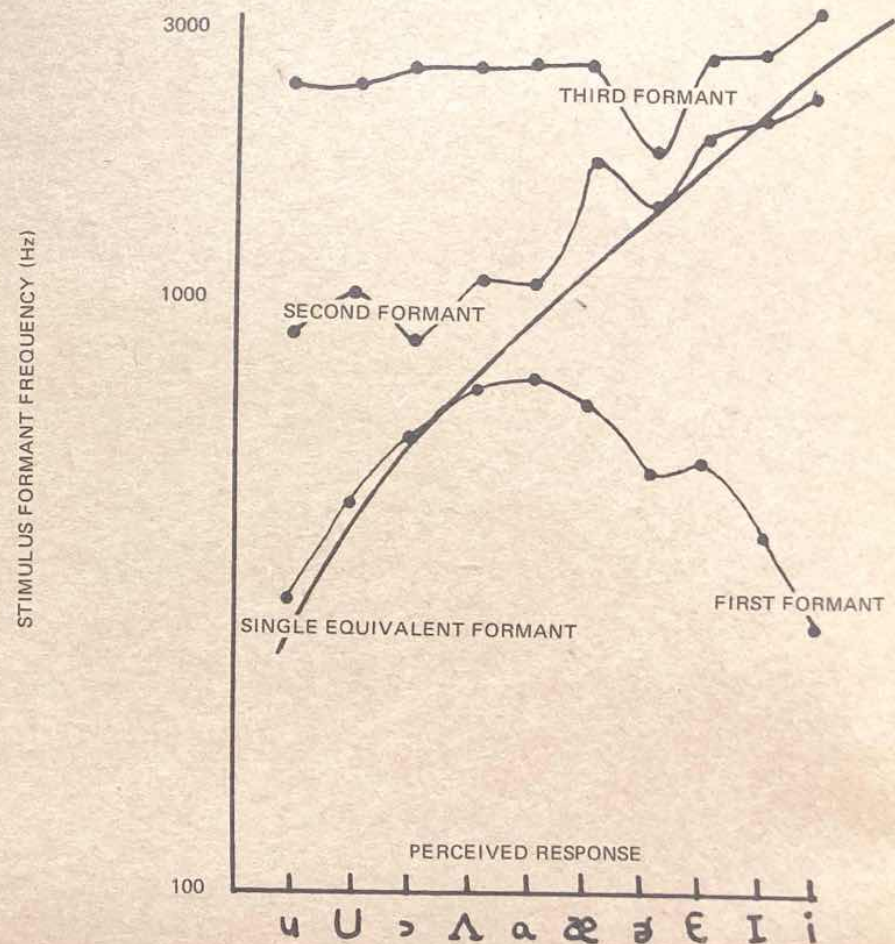


FIGURE 3. BLOCK DIAGRAM OF SEF – FREQUENCY EXTRACTOR

in block form in Figure 3.

The desired time interval can be measured by first determining the location of each glottal impulse in the speech waveform. Separate circuitry (see pitch extractor) was constructed which generates a marker pulse (pitch pulse) after each glottal impulse or after large positive excursions of the input speech waveform. The pitch pulses serve to locate the particular time intervals to be measured. The time relation of the input speech and the pitch pulses is illustrated in Figures 4a and 4c, respectively.

The input speech waveform is first processed by three cascaded logarithmic amplifiers to limit the signal voltage and to precisely define all zero-axis crossings. This signal is used as the input to a Schmitt trigger circuit, the threshold of which is set so that triggering occurs approximately at the zero crossings. However, the exact threshold voltage is not critical because of the limiting action of the preceding stages. The resulting clipped speech waveform is shown in Figure 4b with the appropriate pitch pulses shown in Figure 4c. The leading edge of each pitch pulse is the SET input to a flip-flop, while the negative-going edge of the clipped speech waveform is used as the RESET input of the same flip-flop. Since it is assumed that each pitch pulse is generated within the proper interval to be measured, the flip-flop will be set at some point within this interval and reset at the end of the interval. Thus each pitch pulse need only indicate which excursion of the input speech waveform represents the theoretical SEF period. The trailing edge of each pulse triggers a one-shot multivibrator which generates a 400 microsecond pulse or sample gate. As shown in Figure 4e, the trailing edge of each SEF excursion of the clipped speech wave is coincident with the leading edge of each sample gate. This is shown in Figure 4f.

It will be recalled that the output of the SEF extractor is to be a voltage of which the amplitude at each point in time is proportional to the width of the SEF excursion. A convenient method of obtaining this is by integrating each positive excursion of the clipped speech waveform and sampling the voltage at the peak of the appropriate voltage ramp representing the SEF frequency. The partial schematic diagram of the ramp generator used to integrate each excursion of the clipped speech is shown in Figure 5.

It is seen that when the clipped speech waveform is positive, capacitor C is charged by current source Q_1 . It is discharged by Q_2 when the clipped speech voltage crosses zero and becomes negative. The circuit is then ready to integrate the next excursion of the clipped speech waveform. The resulting ramp voltage and the sample command pulses previously discussed are shown in Figures 6b and 6c, respectively. It is noted that by sampling the waveform in Figure 6b at the points indicated by the sample command pulses, voltages proportional to

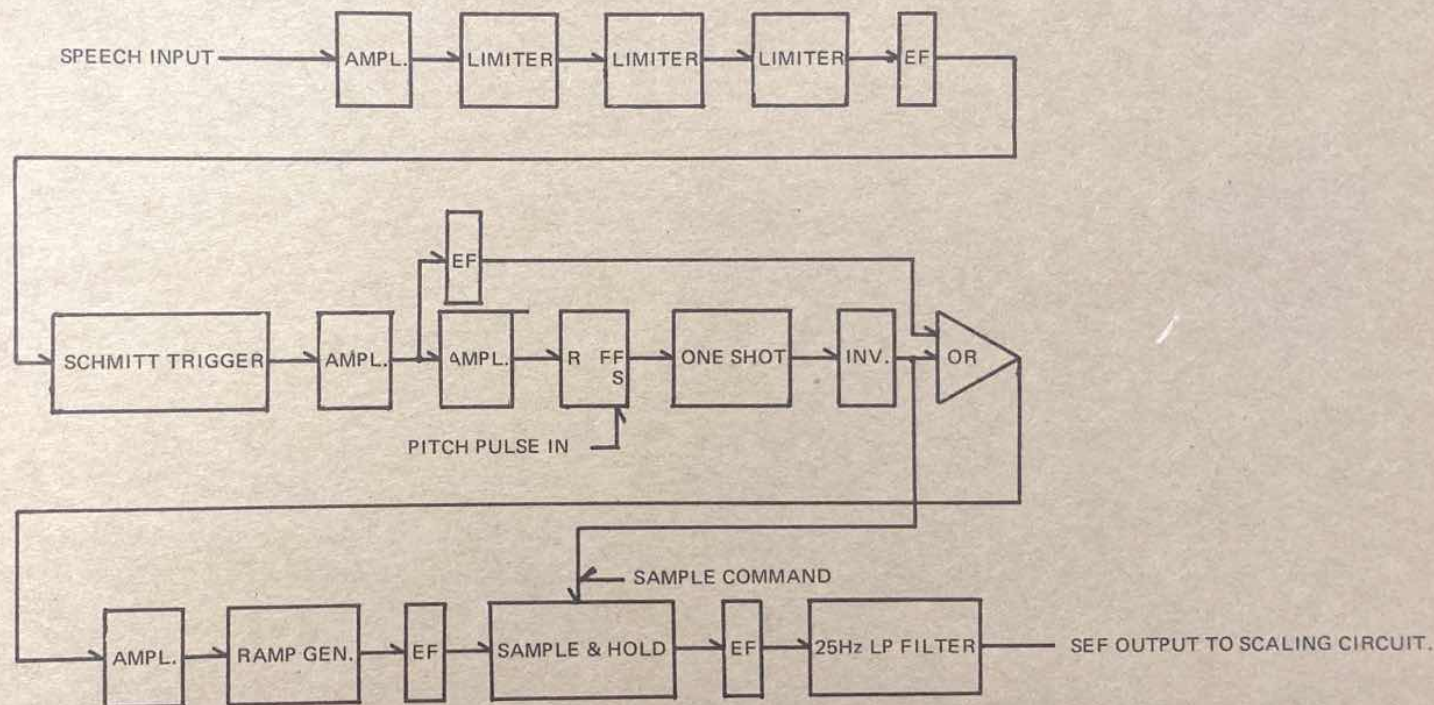


FIGURE 4. WAVEFORMS IN THE SEF-FREQUENCY EXTRACTOR AND THEIR TIME-RELATIONSHIP.

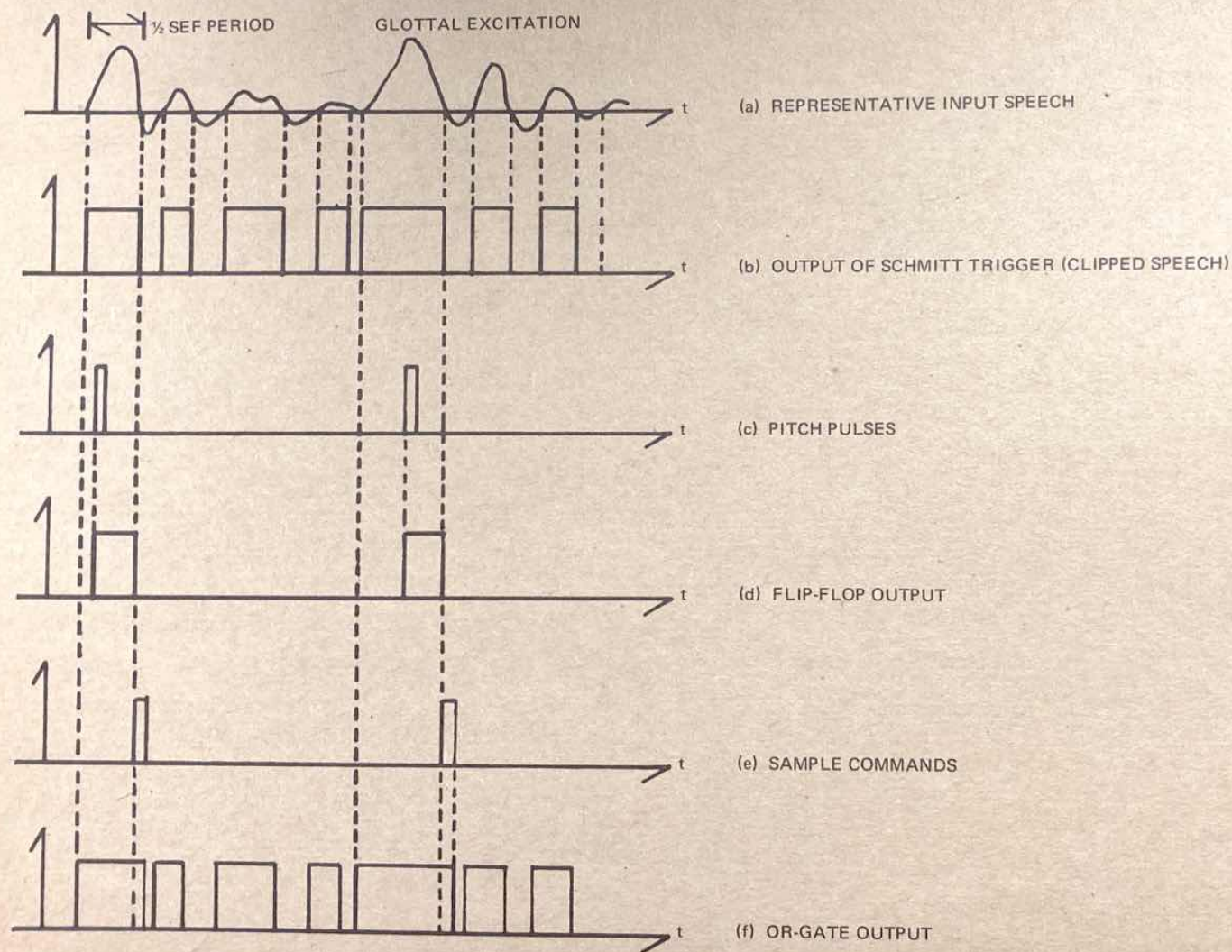


FIGURE 5. PARTIAL SCHEMATIC OF RAMP GENERATOR.

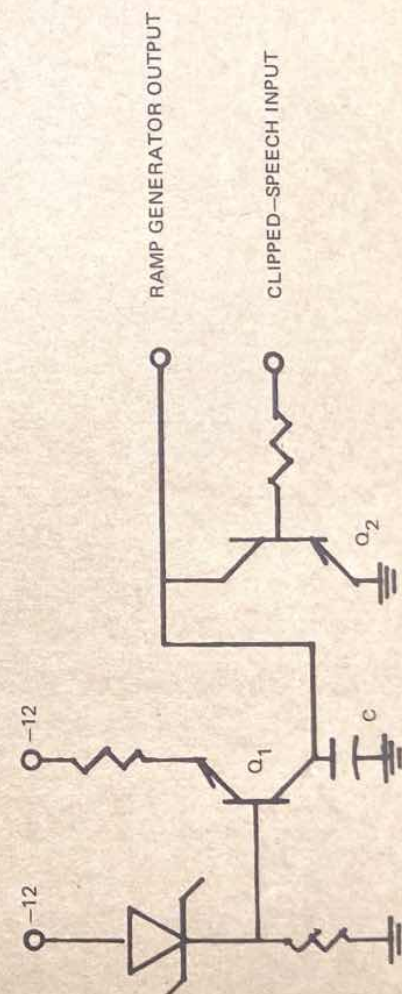


FIGURE 6.

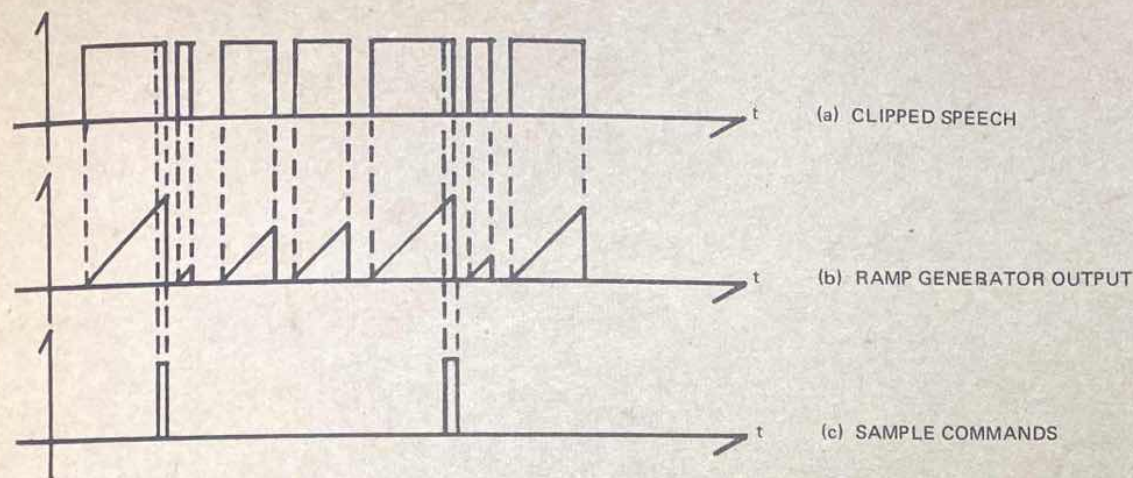


FIGURE 7.

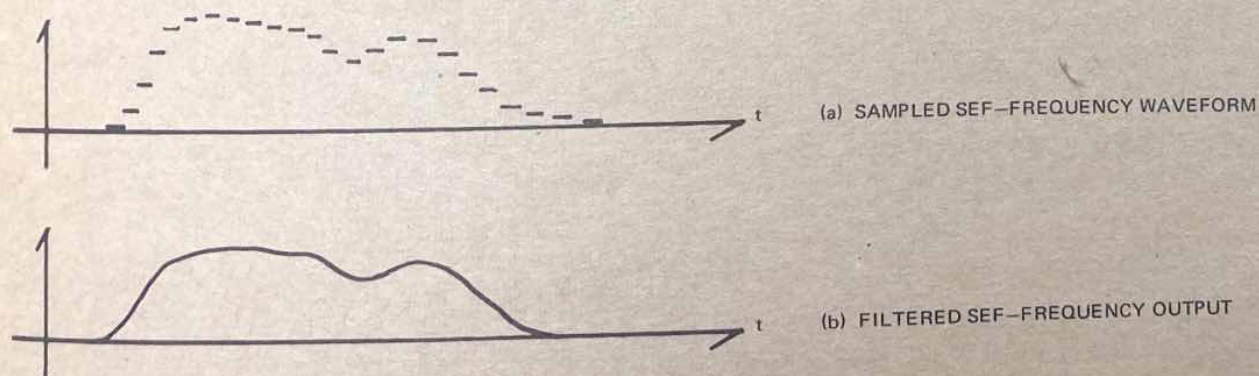
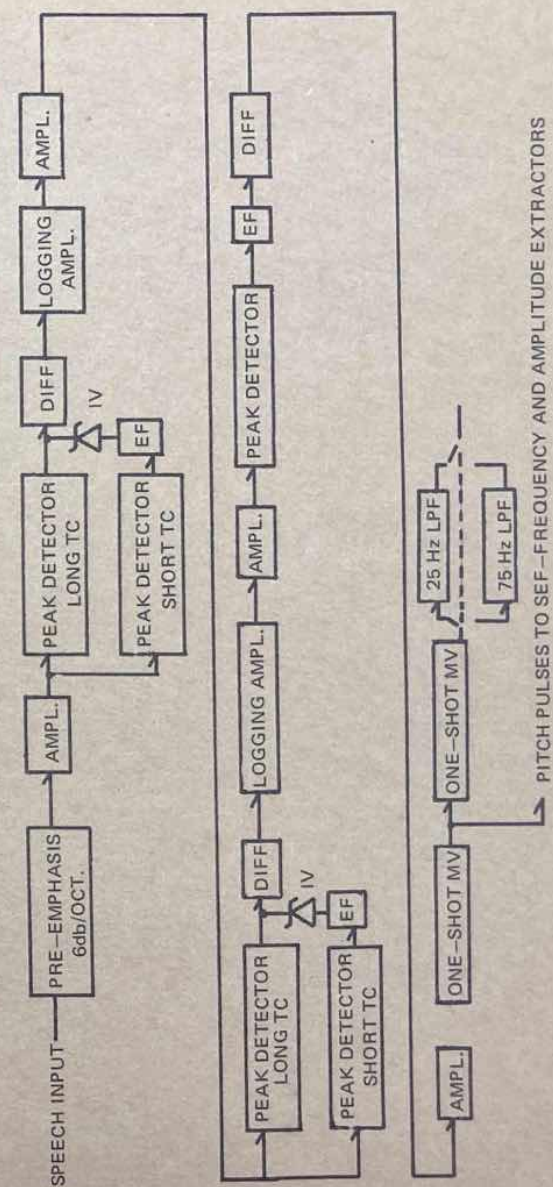


FIGURE 8. BLOCK DIAGRAM OF PITCH EXTRACTOR



the widths of the SEF period are obtained, and all other extraneous excursions of the clipped speech waveform are disregarded. The sample pulse width which was OR'd with the clipped speech waveform ensures that the ramp voltage will not discharge before sampling is completed.

A zero-order hold circuit was used in conjunction with the samples so that the sampled SEF voltage remains constant until it is revised by the next measurement and sample. The sampled SEF voltage waveform shown in Figure 7a is low-pass-filtered to 25 Hz, to provide a smooth SEF signal as shown in Figure 7b. Because of the relatively slow variations in formant frequencies within a given word, little information is lost in the filtering process.

As previously discussed, the period of the SEF frequency can be approximated by twice the period of each first excursion of the speech waveform. Thus the SEF frequency f_{SEF} is given by:

$$f_{SEF} = \frac{1}{2T} \text{ kHz} \quad (1)$$

where T is the width in msec. of the first excursion of the speech waveform. The equation describing the sampled voltage from the ramp generator V_{SEF} is given by:

$$V_{SEF} = K(T+t_s) \quad (2)$$

where t_s is the width in milliseconds of the added sample pulse, and K is an integrating factor. Substituting equation (2) into equation (1), and assuming t_s is negligible in comparison to the SEF period, we have:

$$V_{SEF} = \frac{K}{2f_{SEF}} = \frac{K}{f_{SEF}} \quad (3)$$

Thus the voltage at the output of the SEF extractor is inversely proportional to the theoretical SEF frequency.

PITCH EXTRACTOR

As explained in a previous part of this report, each glottal or noise excitation initiates a complex ringing phenomenon in the oral cavities. The time domain pitch extractor produces a pulse each time this driving function occurs in the speech wave. The period of occurrence of this driving function is directly related to this pitch of the voice as it is perceived by the ear.

The ringing phenomenon in the oral cavities has the greatest amplitude just after the driving function is applied and decays rapidly until the next driving function re-excites the cavities. This is shown in Figure 9. This effect is similar to that produced by a voltage pulse applied to an RLC ringing circuit.

The fact that the speech waveform exhibits large

amplitude swings which decay rapidly makes it feasible to electronically identify the points at which the driving function is applied. This in turn provides the information needed by the SEF extractor circuitry as to which excursion of the waveform represents the SEF period. The pitch extractor is shown in block form in Figure 8. The input speech wave is applied to a high frequency pre-emphasis network and linear and logarithmic amplifiers before being used as the input to a dual-time constant peak detector. A block diagram of this dual peak detector is shown in Figure 10. Both the long and short time constant peak detectors making up the dual peak detector consist of a transistor in the emitter-follower configuration with emitter resistor R shunted by a large capacitor C as shown in Figure 11. As the input signal increases to its peak, the capacitor charges rapidly through the low impedance of the follower. As the input signal begins to decrease, the base-emitter junction of the transistor becomes reverse-biased and the capacitor voltage decays with a time constant determined by the resistor and capacitor combination. As shown in Figure 10, the dual-time-constant peak detector consists of a long and a short time constant peak detector with outputs connected through two series diodes. As the input signal reaches its peak value, both peak detectors charge to this voltage. The total output then follows the slow decay of the long-time-constant peak detector until the series diodes become forward biased, thus clamping the output to the faster decay of the short-time-constant peak detector. This switching takes place when the short-time-constant output has decayed below that of the long-time-constant output by more than the forward voltage drop (1.2 volts) of the two diodes. The output decays rapidly during this period, so that the peak detector will be ready for the next rapid rise in the speech waveform. Figures 12a and 12b illustrate why a single-time-constant peak detector alone may miss a pitch interval, while the dual-time-constant circuit permits a wider range of the acceptable pitch interval (and thus voice pitch) for a given adjustment of the decay constants.

The peak detector output shown in Figure 12b is differentiated to produce a short impulse each time there is a sudden increase in output voltage, indicating the beginning of an SEF interval. This is shown in Figure 12c.

Although the dual-time-constant pitch detector is superior to the single-time-constant circuit, it is not possible to select decay constants which will unambiguously identify the proper pitch pulses, because of the variations of pitch within a word and among different speakers. For this reason, the output of the first peak detector and differentiator is amplified and used as the input to two additional stages of peak-detection differentiation and amplification. This additional signal processing is sufficient to ex-

tract the correct pitch pulses. After the third stage of such processing a one-shot multivibrator is used to produce a pitch pulse at the appropriate point after each rapid use in the speech waveform. The time delay between each glottal excitation and the generation of the pitch pulse will vary to a limited extent depending on the sound spoken and the speaker. However, the pitch detector circuitry will produce the pitch pulse within the SEF period as required by the SEF extractor.

VOICING

The voicing extractor makes a binary decision as to the state of voicing of the input speech signal. Since an unvoiced sound is produced by air passing through a constriction of the mouth or throat, a large amount of high frequency noise will be present. A voiced state is characterized by the absence of high frequency components. The circuitry to be described below measures the average spacing between all zero axis crossings of the speech waveform and determines whether it is short enough to indicate the presence of high frequencies and thus a voiceless state. The degree of voicing at which the circuit will switch state may be varied by potentiometer adjustment. The voicing extractor is shown in block form in Figure 13.

The input speech signal is limited and then clipped by a Schmitt trigger circuit whose threshold is set at zero. The resulting signal is then inverted and both this and the non-inverted signals are differentiated, rectified, and then added. The output is thus a positive impulse at each zero crossing of the speech waveform, which is used to trigger a one-shot multivibrator. Each of these zero crossing marker pulses is used as the input to a ramp generator which produces the waveforms shown in Figures 14a and 14b. It can be seen from these figures that the closer together the marker pulses (indicating the presence of high frequency components) the greater will be the average value of the ramp generator output. Similarly, in the absence of high frequency components, the average spacing of the marker pulses will be large and the average value of the output voltage will be small. This output is low-pass filtered to produce a slowly varying voltage, the amplitude of which is inversely proportional to the average spacing between successive zero-axis crossings of the speech waveform. This voltage is used as the input to a Schmitt trigger which makes the binary decision as to the state of voicing.

AMPLITUDE EXTRACTOR

The amplitude extractor shown in block form in Figure 15, generates a time-domain representation of the log of the amplitude of the SEF frequency. While the SEF frequency is derived from the period of each first excursion after glottal excitation of the speech waveform, amplitude of the SEF is derived from the peak amplitude of this excursion.

The speech signal is amplified linearly and logarithmically and used as the input of a single-time-constant peak detector. The peak detector output, shown in Figure 16b, is sampled at each occurrence of a pitch pulse. Since a pitch pulse is generated at each SEF excursion of the speech waveform, each sample will represent the peak value of this excursion and thus the log of the SEF amplitude. These samples are then filtered to produce a slowly varying analog signal.

The derivative of the SEF log amplitude is used as a recognition parameter rather than the amplitude itself. An operational amplifier is used to provide the derivative output. In order to reduce susceptibility to high-frequency noise, the differentiator is high-frequency limited to 50 Hz. This derivative output is differentiated again to provide the second amplitude derivative as well as the first derivative required by the sampling circuits to be discussed in a following section.

SCALING CIRCUITRY

Two operational amplifiers are used to provide output scaling of the SEF voltage waveform and the amplitude derivative waveform. The gains of these amplifiers are adjusted so that the maximum voltage output for any word is no greater than ten volts, which is the reference voltage of the A/D converters used in the recognition logic.

b - recognition logic

The logic designed to recognize a spoken digit is based upon the values of the three parameters: (a) SEF frequency, (b) SEF log-amplitude-derivative, (c) voicing; all at the sampled points discussed below. A complete recognition logic block diagram is shown in Figure 17. The logic circuitry consists entirely of integrated circuits.

While the voicing parameter is already in binary form, the other two parameters must be quantized. In other words, the analog information has to be converted to digital information. This is done by means of two independent analog-to-digital converters. The A/D converters used in this system consist of Honeywell Micropac Digital Modules. Each converter employs the method of successive approximations with a 13 us per bit computing time. From an analysis of the analog waveforms, it was determined that quantizing the SEF frequency into sixteen levels and the log-amplitude-derivative into eight levels is sufficient for recognition purposes. The outputs of the two converters are then fed into binary-to-decimal decoders whose outputs are the quantized parameter levels.

From Visicorder recordings of a number of different speakers, it was determined that three or four distinct sample points would be sufficient to recognize unambiguously any of the ten digits. The sample points and the method of sampling must be

chosen to meet the following criteria:

- 1) It is necessary to establish the most useful and pertinent points of the three parameter waveforms for word identification purposes.
- 2) The method of sampling should provide data points at the same relative position of the parameter waveforms, independent of the speed with which a word is spoken.
- 3) Relatively simple electronic circuitry should be capable of identifying these points.

The second criterion eliminates the possibility of generating sample pulses at fixed intervals after the beginning of a word. Further, it requires that certain uniform characteristics of the spoken word itself be used as the basis for choosing sampling points. The shapes of the SEF amplitude and its derivative are such characteristics. Two basic shapes of amplitude and its derivative waveforms exist in the limited vocabulary of interest here. These waveforms, along with the chosen sample points are Figures 18a and 18b.

From Figure 18a it is seen that sample point 'A' occurs just after the amplitude derivative waveform peaks. Point 'C' occurs when the derivative waveform reaches zero, after point 'A'. 'C' is thus the first point where the amplitude is constant. 'D', the last sample point, occurs when the derivative first becomes significantly negative. This is the point where the amplitude begins to decrease after a period of constancy.

For the words zero, two, six, and seven, the amplitude waveform is similar to that of Figure 18a, except for a small initial rise. The amplitude waveform and its derivative for this case are shown in Figure 18b. It is noted that the derivative waveform contains a second positive peak which immediately follows the first peak. This peak determines sample point 'B'. The reason for the difference in the two amplitude waveforms can be understood by considering, for example, the word 'two'. The initial 't' sound, which is short-lived, produces the initial rise in amplitude. It is immediately followed by the longer 'oo' sound, producing the remainder of the amplitude waveform. The difference in the number of sample points for the digits zero, two, six, and seven, as compared to the remaining digits is beneficial in serving to isolate two groups of words, thus simplifying identification. It should be noted that sample points 'A' and 'B' require all three parameters for recognition, whereas points 'C' and 'D' occur where the derivative is zero and thus require only two parameters (SEF frequency and voicing) for recognition.

The circuitry designed to extract the sample points from the derivative waveform is shown in block

form in Figure 19. Each of the sample points is identified by using the first and second derivative of the SEF amplitude. Each derivative waveform is applied to two, small-hysteresis, Schmitt trigger circuits, one — the threshold of which is +300 millivolts, and another — the threshold of which is -300 millivolts. These circuits transform each derivative into binary levels. A value greater than the trigger threshold is represented by binary ZERO, while a value less than this voltage is represented by binary ONE. The four binary inputs are processed by logic circuitry to determine where the sample points occur in time. The criteria used to identify these points are listed in Table 1.

As each sample point is identified by the sampling circuitry, the following events take place:

- 1) A 10 us start pulse is generated which initiates the calculate mode of the SEF and amplitude derivative A/D converters.
- 2) Approximately 65 us later the A/D converters signal the completion of the calculate mode.
- 3) At the completion of the calculate mode a 6 millisecond pulse is generated which enables the 'A', 'B', 'C', or 'D' gate banks of the recognition logic.

This time sequence of events is shown in Figures 20a-d.

For each of the sampled points of each word a range of acceptable SEF levels was determined. The same was done for the amplitude derivative. These parameter ranges are synthesized by banks of OR gates. The appropriate combination of SEF frequency range, SEF amplitude derivative range, and voicing decision, with the appropriate enabling pulse is then fed into a NAND gate. This is done for every sample point in the word. When the correct combination occurs, the output of the gate sets a flip-flop (F-F) which stores the recognition of that word segment. When all the flip-flops for a particular digit are set, a NAND gate in the word decoder indicates the recognition of the digit. An example is shown in Figure 21. If the correct combination of parameter ranges is present during the time the 'A' enable pulse exists, all the inputs to gate (1) are high (logic level ONE). The output of the gate is low (logic level ZERO), which in turn sets F-F (1). Similarly, flip-flops (2), (3), and (4) are set in the correct time sequence. When the outputs of all four flip-flops are high, the output of NAND gate (5) is low, which indicates recognition of the word 'two'.

The recognized digit is displayed until it is erased by the start of the next word. The SEF amplitude waveform directly controls the resetting of all the flip-flops in the memory bank. A 10 us erase pulse is generated by the switching of a Schmitt trigger when the amplitude waveform rises above a present

level. This occurs prior to the 'A' segment of the next word, as shown in Figure 20e. This permits continuous recognition without the need for manually resetting the system.

The display used in the system consists of a seven-segment numeric readout with associated encoding logic.

RESULTS

The performance of the parameter extractors is illustrated in Figures 22 and 23. Figure 22 is the Visicorder recording of the parameters (SEF frequency, SEF log-amplitude-derivative, and voicing) for the ten digits spoken by one of the authors. A visual analysis of this recording indicates that the parameter waveforms for each digit are indeed unique in shape and amplitude when compared to those of the other digits. Figure 23 shows Visicorder recordings of the three parameters for one of the digits, in this case 'five', spoken by three other persons. It indicates the basic invariance of the waveforms for a particular digit among different speakers.

System performance was evaluated by having each of the authors speak each digit twenty times, as well as having four other persons speak each digit ten times. All speakers were asked to speak clearly. The ability of the system to recognize the digits zero through nine, as spoken by the authors, is demonstrated by the recognition matrix shown in Table II. As indicated by this matrix, the system performed with as high as 90% recognition, as low as 10% non-recognition, and an average of 4% mis-recognition. For the other speakers, system performance was not as high. Non-recognition is defined as no response on the digital display to a spoken word. Mis-recognition is defined as appearance on the digital display of a figure other than that corresponding to the spoken digit.

The speed of response of the system to a spoken word is instantaneous in the sense that the last parameter sample to be processed by the recognition logic occurs several milliseconds before the actual end of the word. Since processing time is in the order of microseconds, the display is lighted prior to the end of the word. The recognition rate (i.e., the number of words per minute to which the system is capable of responding) is limited only by the restriction that there must be a definite interval of silence between words. If one word is slurred into the following one, the system will not reset itself and therefore will continue to display the previously recognized digit.

When non-recognition occurred, the parameter waveforms for that digit were still close in shape and amplitude to those yielding the proper response. However, some parameter values at the chosen sample points were just beyond the limit of design

tolerance. It was found that the recognition improved significantly after the speaker had some practice in using the device.

CONCLUSIONS

1. The speech recognition system, as designed, successfully identified and displayed the spoken digits zero through nine. Recognition performance was satisfactory for words spoken in a clear voice. The system is capable of recognizing words spoken by different persons without the need for adjustment. This indicates the merit of designing a limited-vocabulary speech recognition system on the basis of the Single Equivalent Formant concept.
2. The use of a limited vocabulary in the design of this speech recognition device allows a realistic degree of logic complexity while providing an extremely useful vocabulary. The analog parameter extractors used in this system are by no means limited to the vocabulary of interest here. They are completely applicable for extended vocabularies without any modification. The digital logic circuitry would have to be modified and expanded to accommodate other vocabularies. The only restriction that must be placed on an extended vocabulary is that it be limited in order for the recognition logic to be feasible from an engineering point of view.
3. Recognition accuracy can be improved by selecting more sample points for the recognition logic to evaluate. Increasing the number of criteria needed for recognition of a word would reduce the possibility of a mis-recognition. It would also permit wider parameter tolerances at each sample point, thereby also reducing non-recognition. However, improvements attained by doing this should be evaluated with respect to the increase in complexity of the logic circuitry required.
4. Human adaptability to the system is a factor in improving its performance. In any man-machine interface it will usually be found that the human can adapt more readily to the machine than vice-versa.

NOTES

1. Homer Dudley and S. Balashek, 'Automatic Recognition of Phonetic Patterns in Speech', The Journal of the Acoustical Society of America, volume 30, no. 8, August 1958.
2. Louis R. Focht, 'The Single Equivalent Formant' presented to the IEEE International Communications Conference, Philadelphia, Pa., June 16, 1966.
3. Focht, 'The Single Equivalent Formant', pp. 14-15.
4. Honeywell Model 1508 eight-channel Visicorder Oscillograph in conjunction with Accudata 117 amplifiers.

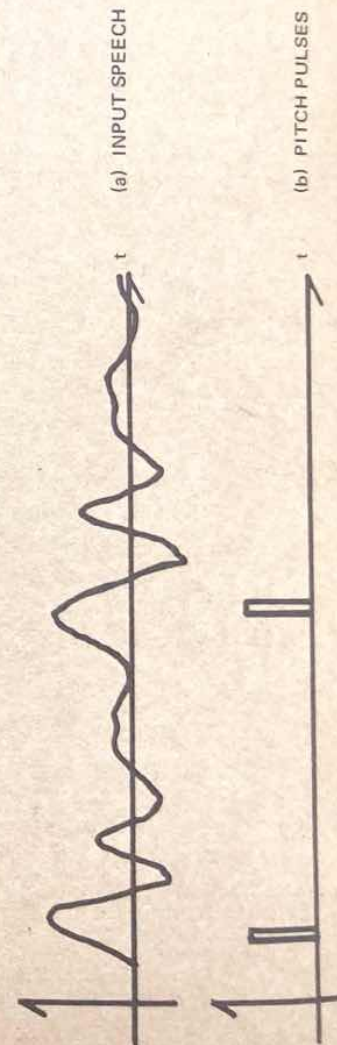


FIGURE 10. DUAL-TIME-CONSTANT PEAK DETECTOR BLOCK DIAGRAM.

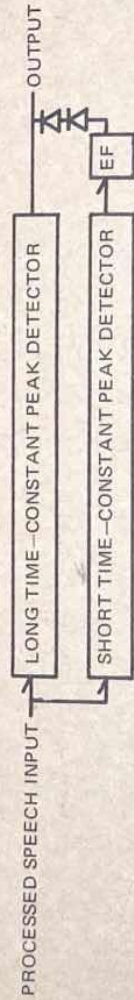


FIGURE 11. PEAK DETECTOR

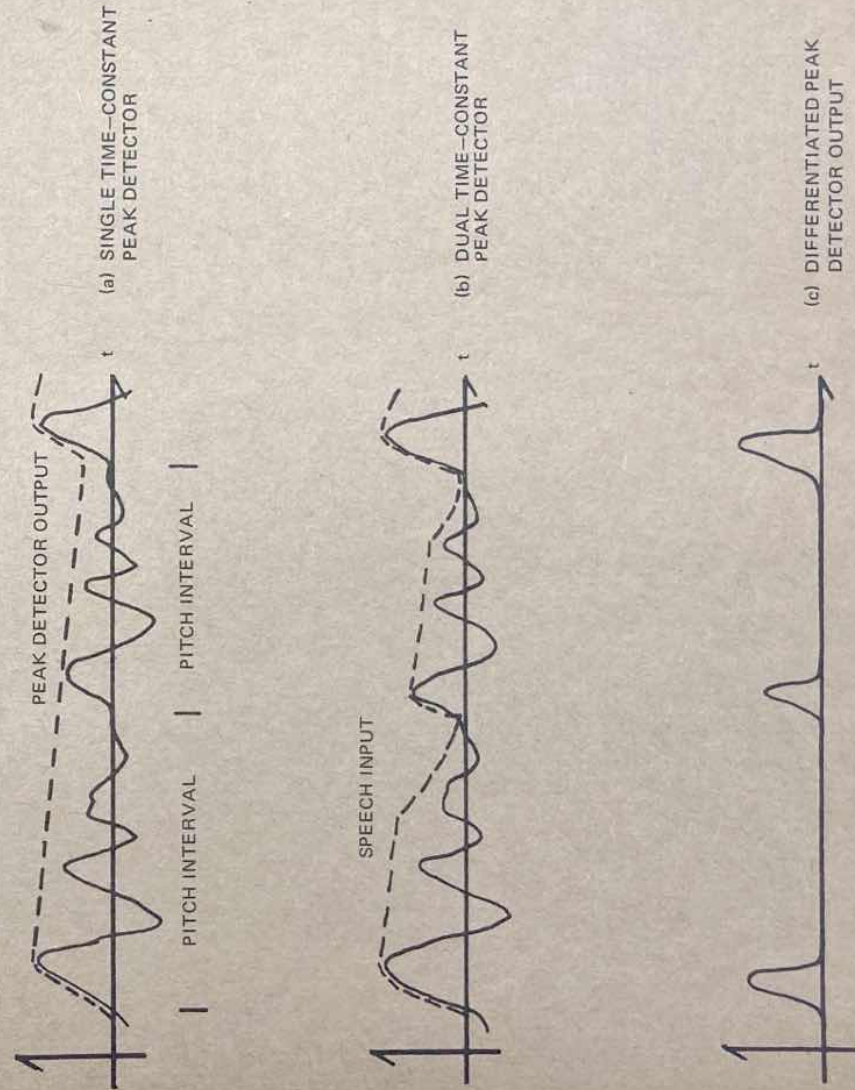
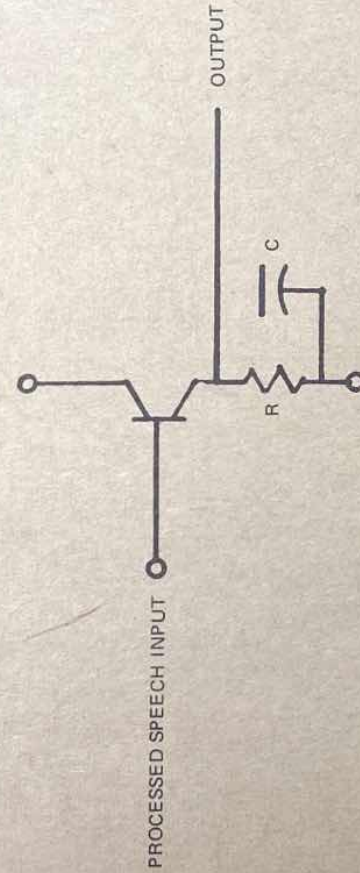


FIGURE 12.

FIGURE 13. BLOCK DIAGRAM OF VOICING EXTRACTOR.

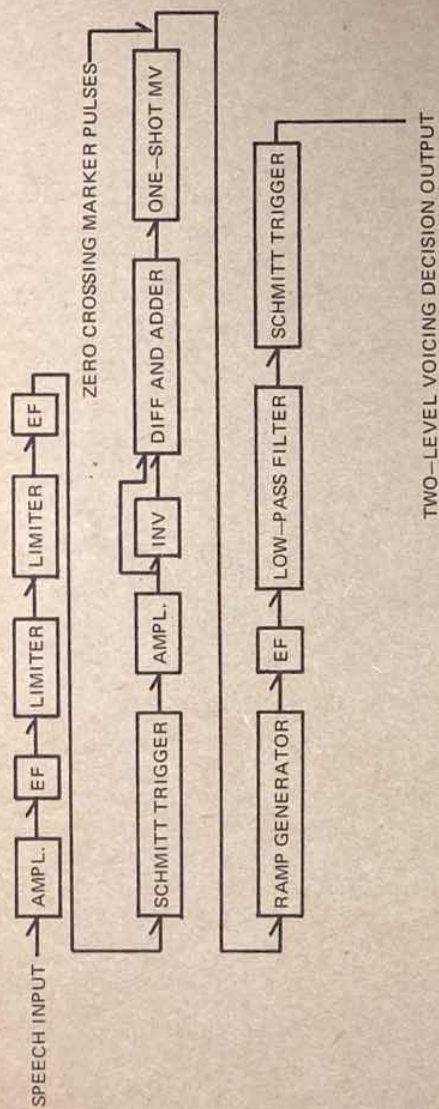


FIGURE 14. ZERO CROSSING MARKER PULSES AND RAMP GENERATOR OUTPUT.

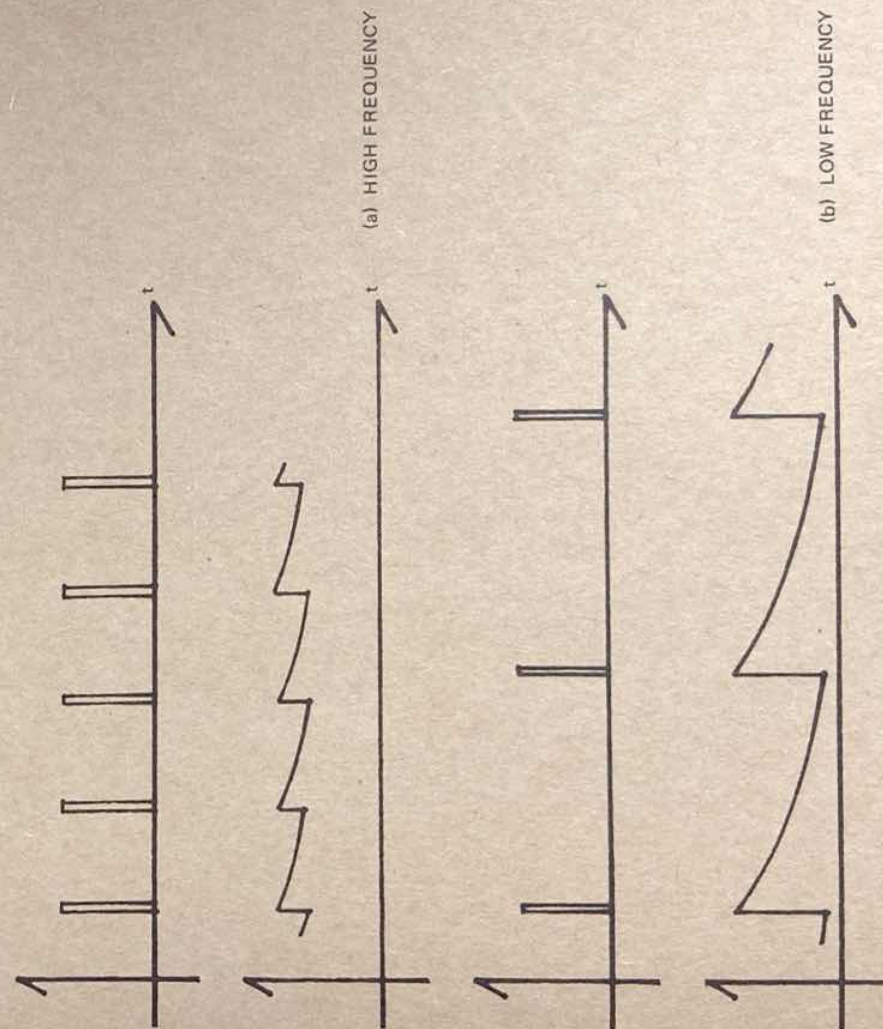


FIGURE 15. BLOCK DIAGRAM OF AMPLITUDE EXTRACTOR.

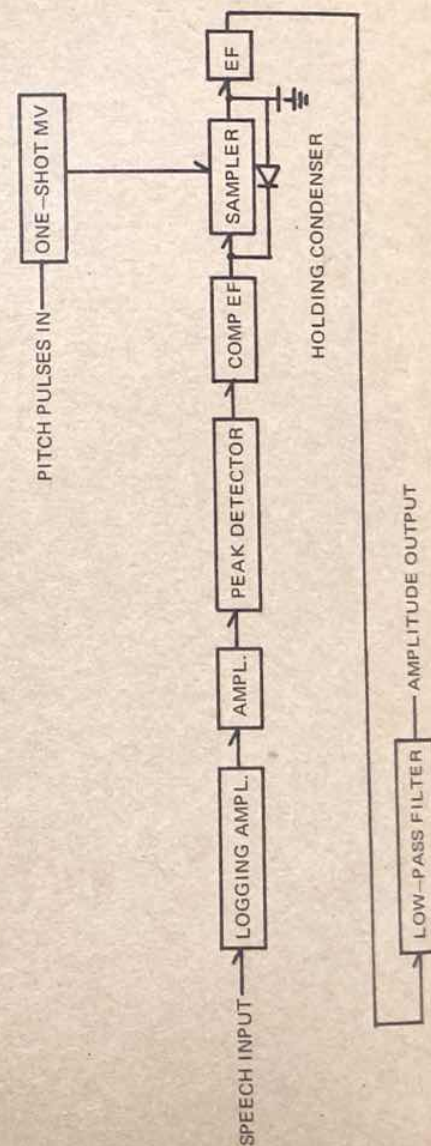


FIGURE 16. AMPLITUDE EXTRACTOR WAVEFORMS.

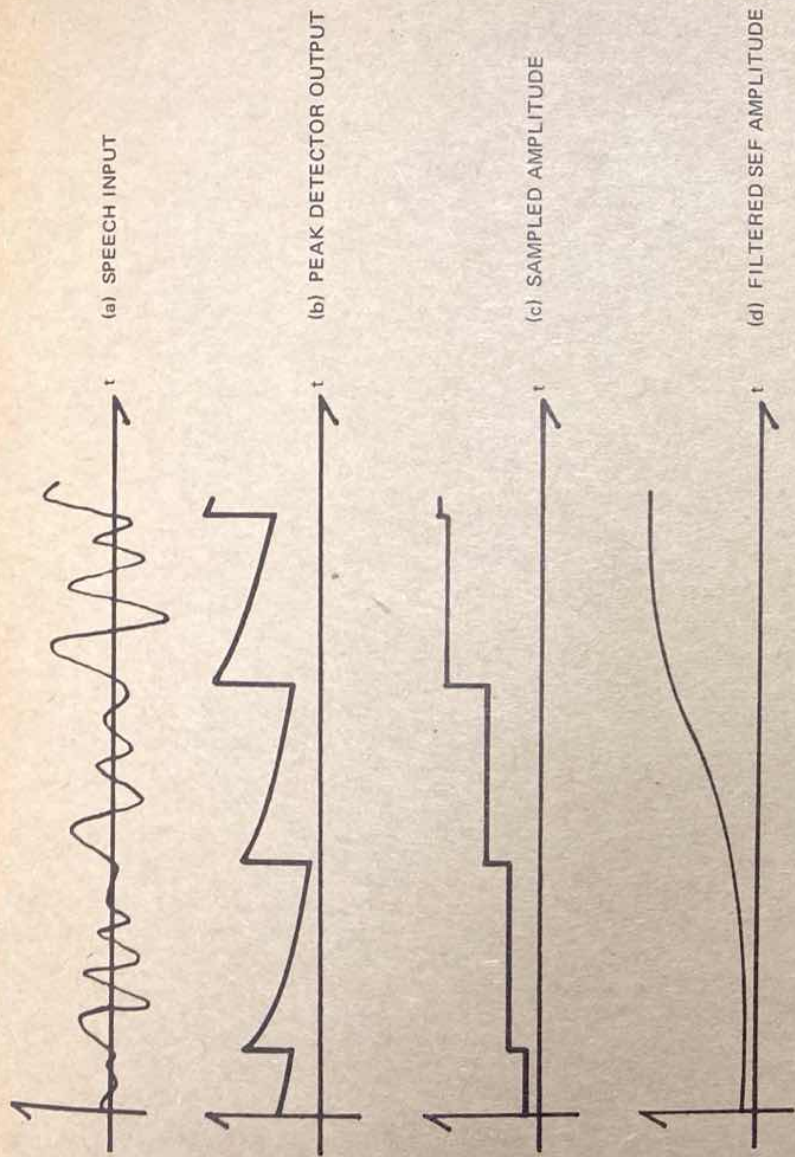


FIGURE 17. RECOGNITION LOGIC BLOCK DIAGRAM.

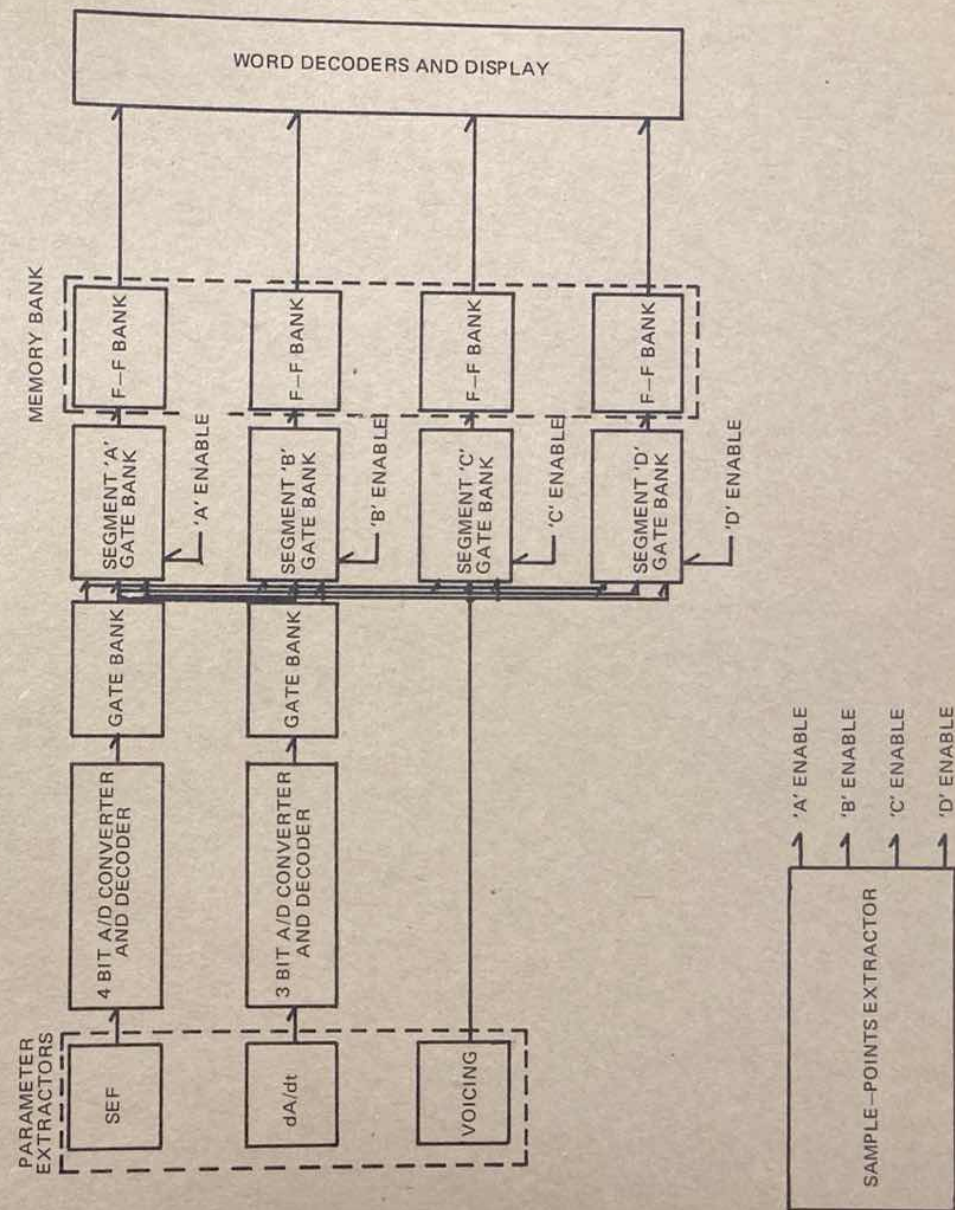


FIGURE 18. BASIC SHAPES OF SEF-AMPLITUDE AND ITS DERIVATIVE.

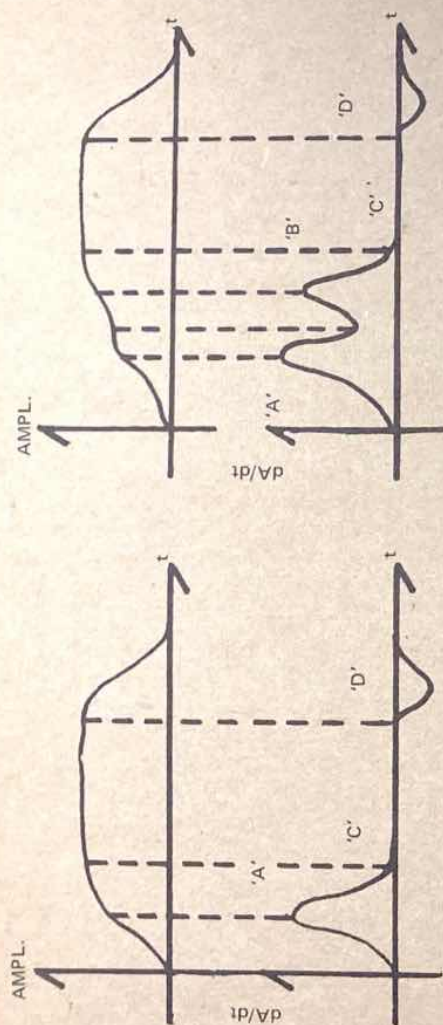


FIGURE 19. BLOCK DIAGRAM OF SAMPLE-POINTS EXTRACTOR.

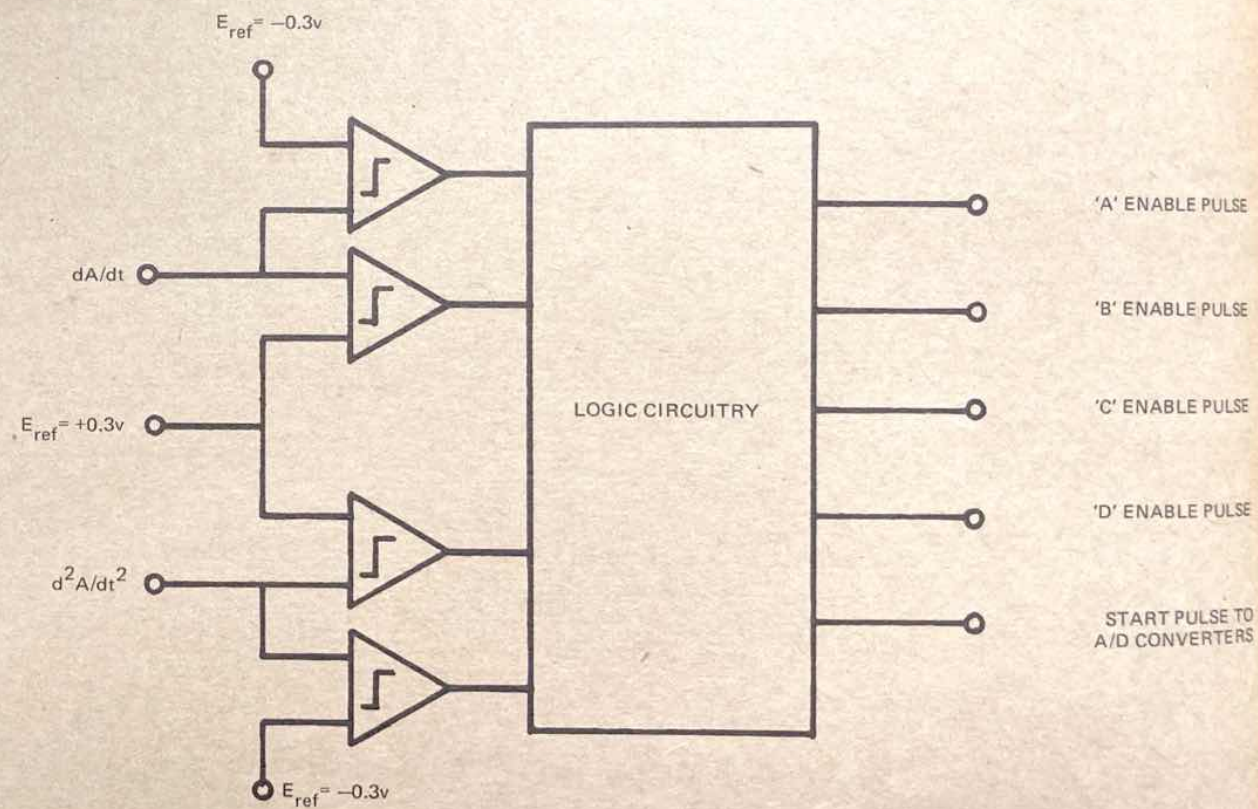


FIGURE 20.

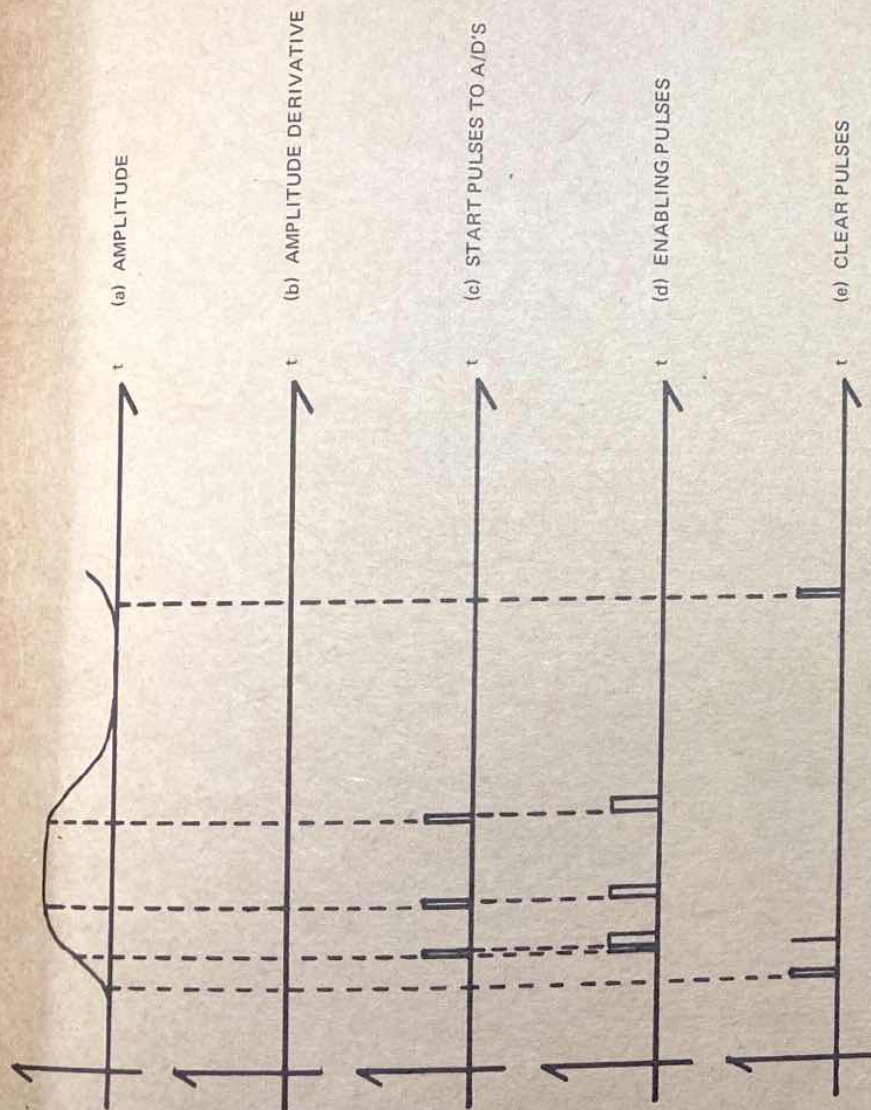


FIGURE 21. RECOGNITION LOGIC FOR 'TWO'

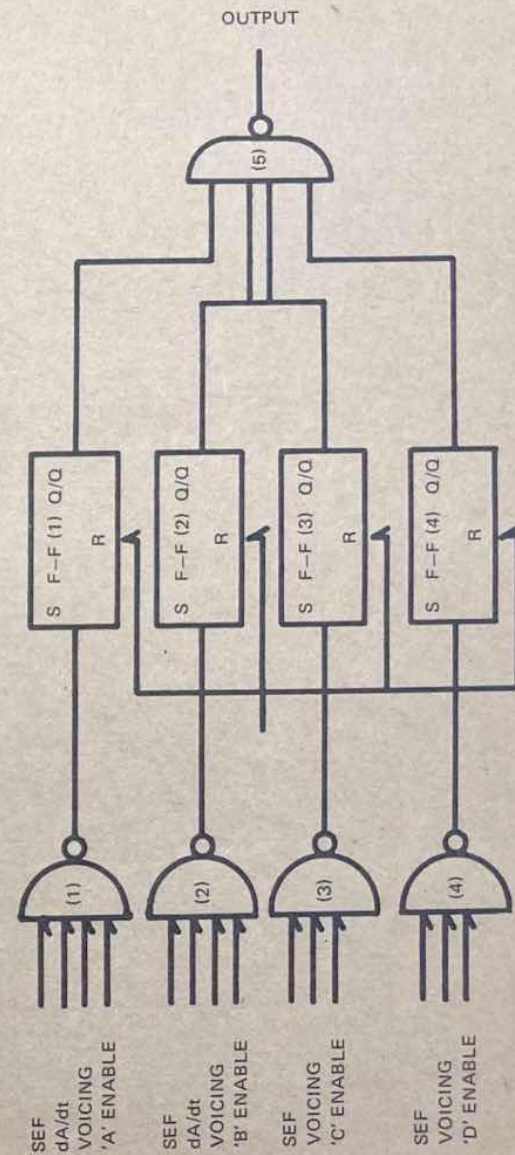
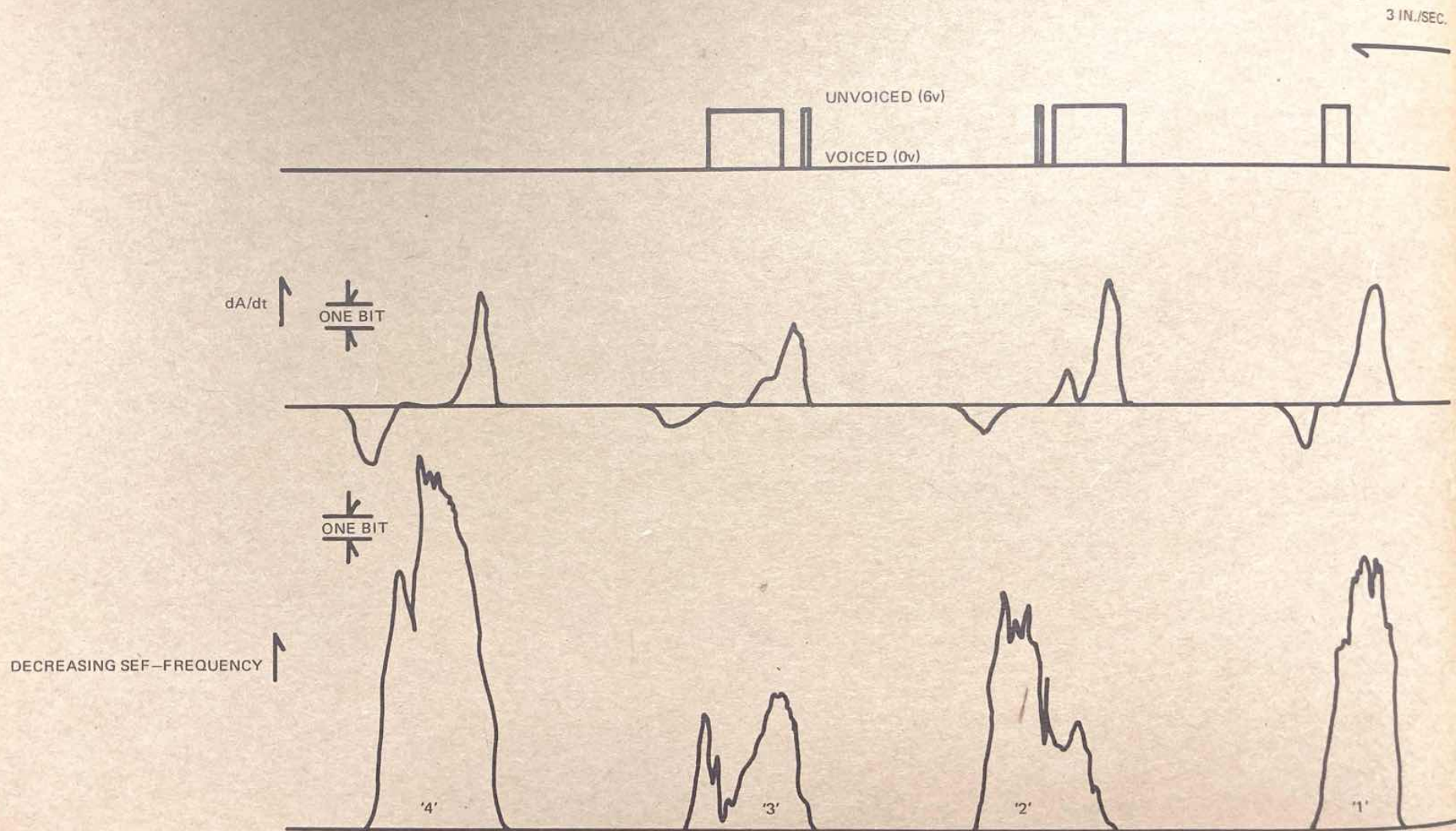
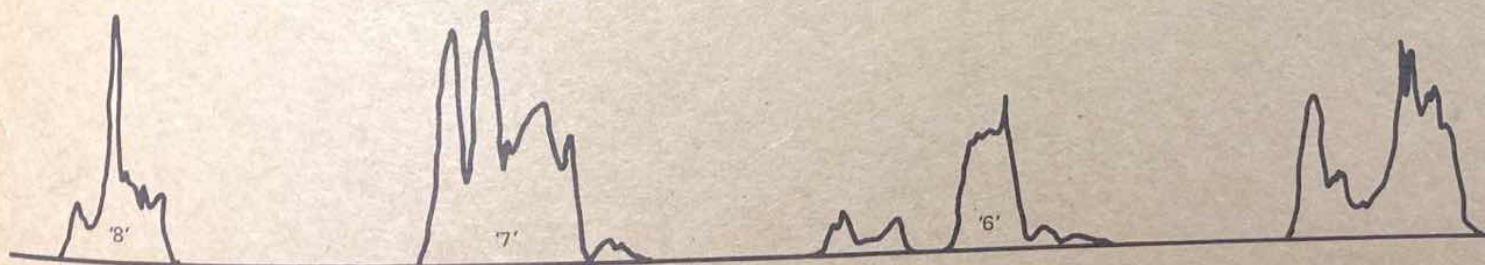
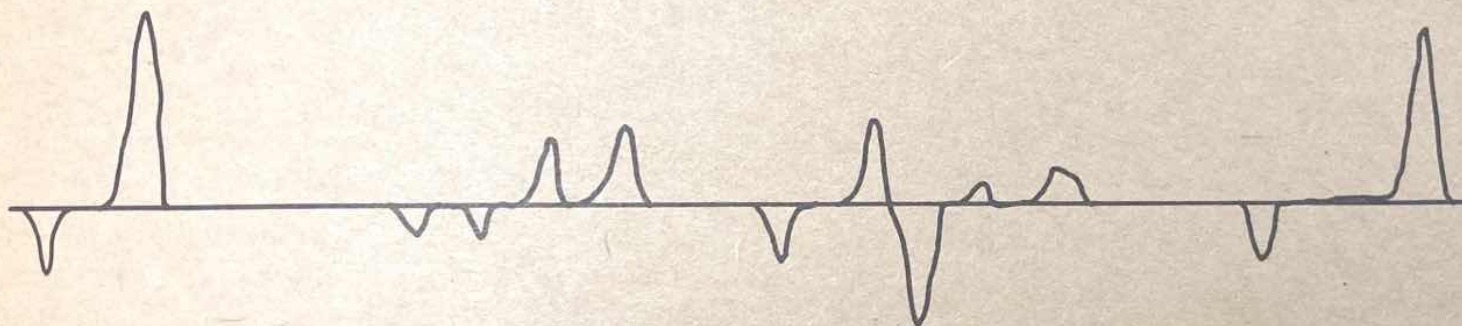


FIGURE 22. VISICORDER RECORDINGS OF 'ZERO' THROUGH 'NINE'.





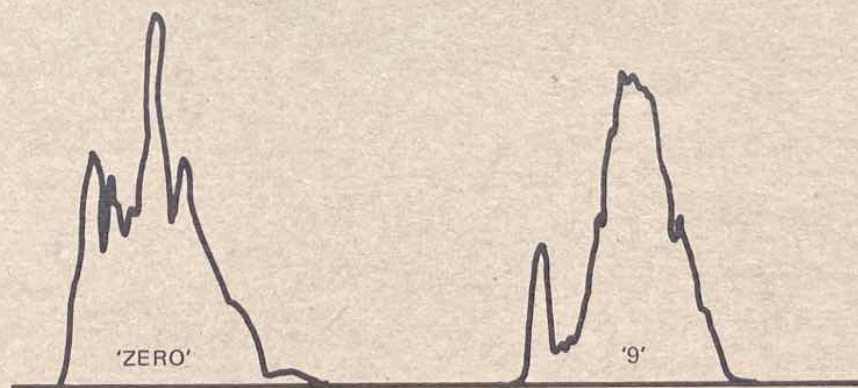
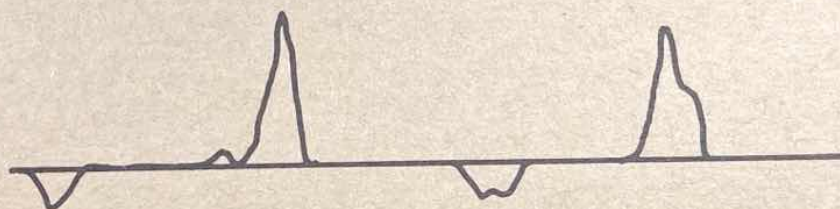


FIGURE 23. 'FIVE'

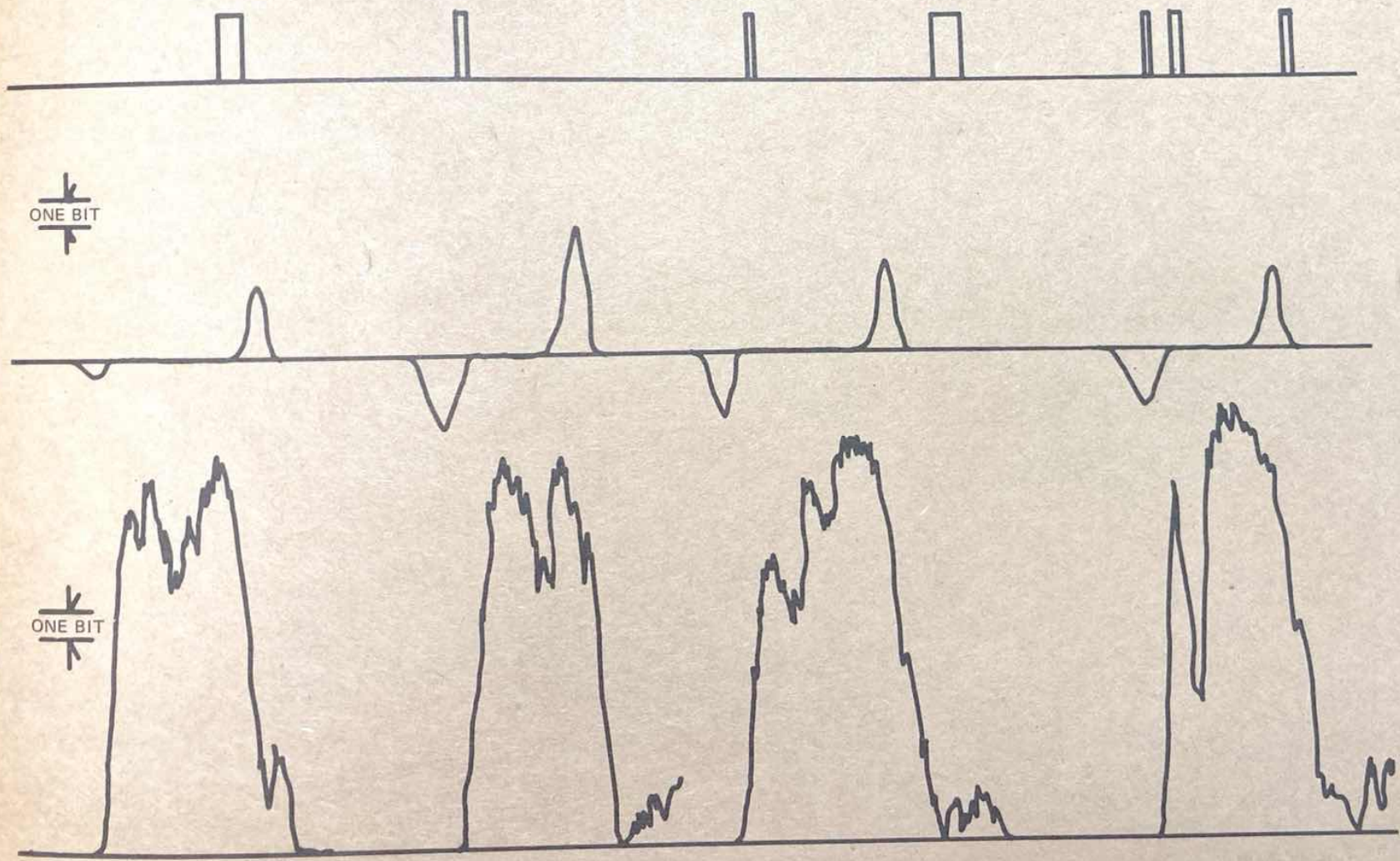


TABLE I

SAMPLE POINT	D	dA/dt	d ² A/dt ²	ADDITIONAL CRITERIA
'A'		+3v	-.3v	
'B'		+3v	-.3v	'A' HAS OCCURRED
'C'		+3v	+3v	'A' HAS OCCURRED
'D'		-.3v	-.3v	'C' HAS OCCURRED

TABLE II. SYSTEM PERFORMANCE RECOGNITION MATRIX (FORTY TRIALS PER DIGIT)

SPOKEN DIGIT	RESPONSE										
	0	1	2	3	4	5	6	7	8	9	OTHER *
0	26										
1		20				2					
2	4		22								
3			2	24						2	10
4					34						
5		2			33	33					
6							31				
7	4			2				21			
8									36		
9				2						25	7

* SIMULTANEOUS RECOGNITION OF TWO DIGITS.

The proper activity of the architect-engineer is purposeful. It is not to devise a better society so as to arrive at a finer architecture; it is to provide a better architecture in order to arrive at a more desirable society.

Theodore Larson

THE PHENOMENON OF ARCHITECTURE

ALLAN WALLIS

THE ARCHITECTURE OF PLANNING

The factor which most clearly defines architecture as modern is planning. Planning neither merely nor mainly as the process of design conducted on an enlarged scale, but planning as the ancient desire coupled with an emerging technological ability to control environment — and through environment — man himself. The architecture of planning is an architecture grown self-conscious: conscious of the world of possibilities revealed by science, and self-conscious of its potential place in that world.

The development of an architecture of planning rests upon two basic assumptions. It is assumed that there is a phenomenal quality in architecture, which, separate and apart from the 'ineffable aesthetic experience', meaningfully and measurably affects human existence. It further assumes that through the construction of a model of causal reality, this quality can be controlled.

These assumptions have emerged over the past two centuries as the consequence of a dual revolution. A revolution in technology addressing itself to the problem of alleviating human necessity: and a revolution in the natural and social sciences, addressing itself to the problem of defining that necessity. The source of most modern architectural theory may be traced to the attempt to rationalize the process of form-making about the consequences of this dual revolution.

As early as Viollet-Le-Duc, through the machine age theorists to the most current work in systems design, the goal has been the creation of a unitary and holistic theory of form. From the perusal of such attempts it might be suggested that the modern age is in search of its own Palladio; his original

theories having been relegated by the advance of a 'modern situation'.

While these theorists have managed to agree on the consequences of the revolution in technology as they concern the pragmatics of form, their interpretation of the consequences of the social revolution has tended to weight their conclusions along the entire gamut of philosophic speculation. From the conclusion that architecture has nothing to do with these issues, producing a self-assured if not somewhat defiant formalism; to the conclusion that it is central to these issues, producing at times an architecture of process which may or may not result in form.

Among the attempts to create a holistic theory of architecture about the concepts of planning, the work of Le Corbusier emerges, not as an attempt to dogmatically simplify the often conflicting issues addressing architecture, but as an attempt to synthesize them. The evidence for planning became at once the cause for theory and the foundation of a meta-architecture.

PHENOMENOLOGY

The plan is the generator.

The plan holds within itself the essence of sensation.¹

The plan is the generator. It is a state of equilibrium within a dual reality: a causal or operational reality and a symbolic reality which attempts to apprehend it. These two realities are inexorably mixed in the architecture of an epoch; their progressive extension marking the development of succeeding epochs. Every progression, every new epoch, eventually demands a new equilibrium. This equilibrium defines a classical state of creation — a state of repose.

My work, my searching, is to try to put modern man away from bad times, away from catastrophe, to put him in happiness, joy, and in harmony.²

The catastrophe of the present era is 'unconscious creation' — effort without a stated goal. Creation should be purposeful. Its goal is to put man back into harmony with nature and with himself; in short, to establish an equilibrium. The conscious and willful creation of harmony, however, requires the construction of a causal theory. A model in which the creator and his creations are seen as part of one developmental continuum; a construct in which man and his inventions are seen to exist symbiotically. The metaphorical expression of, and the mechanism for operation within this symbiotic continuum, is the plan.

THE THEME OF PURISM

The essay 'Purism' was a proposition in causality. It proposed that the historic development of architecture be considered a progressive extension of biological evolution. Thus the rules which applied to natural creation could be used to define and direct 'purposeful creation'. It reasoned the potential of human invention, as natural invention, resolves itself either in the production of the ornamental and wasteful or in the purposeful. Purpose in nature, as in willful invention, being rapidly evinced by its survival value. The laws of natural selection thus exact a strict criteria upon adaptations; the application of Darwin's laws to mechanical invention promised to provide an equally valid and severe criterion.

Both natural selection and mechanical selection are manifestations of purification.³

Darwin's model of evolution, however, avoided any conclusions concerning the 'final purpose' of the process of selection. Purism, while accepting his notion of the immediate purpose of natural selection, added to it the vitalist's proposition that evolution was teleological.⁴ Both mechanical selection and natural adaptation were processes of purification — the invention and refinement of artifacts or object-types about necessities or object-themes. Thus Purism provided a model for creation within a continuum of change; but it

suggested that the change was directed towards an ultimate and purposeful objective 'purification' — the realization of an *a priori* idea: an ideal man in an ideal universe.

The **object-theme** is a term used here to express a universal necessity. It is defined as the program for the mechanical completion of the human organism. The **object-type** is a response to theme. Beyond local factors of deformation, it is an artifact or invention common to all humanity. Le Corbusier and Ozenfant hold that the process of purification tends to evolve the object-type towards increasingly geometric shapes. The pure geometric shape, their reasoning continues, being the source of a 'primary sensation'. The perfected type, equated biologically rather than culturally, is understood to evoke a universal (and therefore predictable) sense response in all men. Thus the process of purification is a development towards pure emotions, as well as pure mechanisms.

...a work of art should induce a sensation of a mathematical order, and the means of inducing this mathematical order should be sought amongst universal means.⁵

Classical theories of art were metaphysical; non-evolutionary. Purism, however, in drawing an analogy between art and biological evolution, attempts to put aesthetic theory both on a scientific basis and within a dialectic frame. But in suggesting that evolution is teleological, it implied that a metaphysical or spatial frame superseded the dialectic model. Thus Purism, while recognizing the necessity of a dialectic development to explain the relation between various periods of art, ultimately returns to a classical foundation in metaphysics.

In Descartes's cosmology, which Le Corbusier was undoubtedly familiar with, category is placed over relatedness and quality. Qualities such as joy and happiness are equated in terms of their generative causal components. Similarly, the object-theme, as an expression of program, is understood as being realized through the object-type, an expression of form. An exacting synthesis between theme and form defines the **ideal-type**. Progress is the development of ideal-types through the

self-conscious extension of the process of purification: man perfecting man through his self-made image.

Purism reiterates the major points of the Euclidean model, in that both hold that the role of the architect rests in the recognition and acceptance of the universal type, and that the perfection of type is expressed through the transcendental purity of geometry.

Man created by the universe is the sum of that universe....he proceeds according to its laws and believes he can read them, and make of them a coherent scheme....this knowledge does not put him in opposition to the universe; it puts him in harmony with it, he is therefore right to do as he does, he could not do otherwise....⁶

Purism was an expression of both the nineteenth century's enthusiasm for the dialectic, and the optimism which it held in science and technology. The world revealed by science promised to lift the yoke of sin from man by disproving religion, returning to man his license to free will. 'Whatever is and is not ashamed of being, is good', is an expression that might be attributed to many spokesmen of the age. 'Man, in following his intuition can only produce that which is in harmony with Nature's Plan.' The biological analogy which formed the foundation of planning spoke also of the inevitability of certain social situations, and of the 'natural morality' of man's domination over nature and over himself. The moral directives which it gave creativity rest in the unitary and formalistic satisfaction of technological intuition. Its rational pursuit promised the ultimate liberation of man.

The optimism which marked the nineteenth century was to be eroded by the discoveries of the early twentieth century. Rationality proved to be a quality far harder to obtain and even to accept, than had been initially supposed. In Freud's concept of Meta-Psychology, for example, the advance of technology and civilization was equated as inversely, rather than as directly, related to the attainment of intuited freedom and happiness.⁸ The advance of society meant the re-

pression of the individual. Le Corbusier was undoubtedly speaking to this alternate reality when he wrote that planning rests in an optimistic faith in humanity. That which started as faith and aspired to science returned again to faith.

THE IDEA OF PLANNING

Mies van der Rohe is credited with the statement: 'Architecture is the will of an epoch translated into space.' Le Corbusier makes similar remarks in *Towards a New Architecture*; indeed, the notion was apparently common amongst machine age theorists.

The statement, 'Architecture is the will of an epoch translated into space', suggests that form is posited *a posteriori* to a change in societal structure. It understands the function of form to be the symbolic affirmation of what, in light of technological advancement, is perceived as 'ultimate reality'. Alienation, with respect to this model, is a product of disequilibrium between realities: between type and technological capacity; between object-theme and object-type. It is the consequence of unconscious creation. Equilibrium, on the other hand, and the correspondance between social phenomena and formal type, culturally defines a state of 'rational architecture' — the product of purposeful creation.

There reigns a great disagreement between the modern state of mind, which is an admonition to us, and the stifling accumulation of age-long detritus.

*The problem is one of adaptation in which the realities of our life are in question.*⁹

Planning is architecture grown self-conscious. It is the recognition that architecture emerges *a posteriori* to a change in societal structure; its function has been one of affirmation rather than generation. Planning suggests that the symbolic reality posited by architecture as affirmation of a change in structure, can in anticipation of technological change preceed and absorb it. In anticipation of the alienation resulting from

change, architecture can *a priori* create a new symbolic reality and avoid disequilibrium. Rather than the will of an epoch, planning suggests that architecture assume the position of the generator of an epoch.¹⁰

We must create the mass-production spirit.

The spirit of constructing mass-production housing.

*The spirit of living in mass-production housing.*¹¹

Change, rather than becoming an endless heraclitean flux without purpose or direction, becomes instead, the mechanism of evolutionary purification for the phenomenal object-type. The creation of the object-type respects the notion that 'form follows function', but it suggests in addition that the corollary to the statement be held equally binding, that function follows form. That is to say, the formal image makes the operational reality possible; it gives the flux of existence an operational scale.

Society is filled with a violent desire for something which it may obtain or may not: everything depends on the effort made and the attention paid to these alarming symptoms. Architecture or Revolution.

*Revolution can be avoided.*¹²

DETERMINACY

To Le Corbusier, the creation of architecture was a matter of passion — yet planning, to which it was inexorably linked was to be pursued dispassionately. The criteria for an architecture of planning were not to be derived from academic aesthetics. The recognition, though not the proof, of a phenomenal quality in architecture had removed criteria from the realm of the academic and placed it in the sphere of the moral. The creation of form under the theory of planning was a matter of passion tempered by the moral obligations of creation: the recognition of willful determinacy.

Having thus defined and recognized the phenomenon of an

architecture of planning, the problem of determinacy now emerges. If architecture is indeed symbiotically related to man, then should it not discipline itself accordingly? In the very formulation of the issues defining the relationship, Le Corbusier had already indicated the nature of this discipline.

The laws of nature and the laws of man.

Since man is a product of nature, the laws he lays down must accord with those of nature.¹³

The determination of type lies neither in the total optimization of free-will nor in the furthest extension of collective effort. Determinacy, as in the Euclidean World, rests in the establishment of a spatial frame (moira) and in demarcation within that frame of the collective and individual spheres of action (nomos). Freedom under planning consists of the exercise of choice within the confines of frame. It is the conscious acknowledgement of collective necessity. This concept suggests a metaphoric interpretation of *Le Plan Libre*, a title which, as *Maison Domino* and *Maison Citrohan*, bears a double meaning. It is a spatial frame, defined by columns, in which biomorphic movement is calculated and contained; it is a microcosm of planning.

The actions of man, Le Corbusier concluded, in order to be moral and correct, must respond to the laws of nature. These laws as revealed by Darwin in his theory of evolution and by Maxwell in his thermodynamics, are expressions of one basic factor — economy.

When examining these selected forms, one finds a tendency towards identical aspects, corresponding to constant functions; functions which are of maximum strength, maximum efficiency, maximum capacity, etc.; that is, maximum economy. Economy is the law of natural selection.¹⁴

Economy itself reveals a dialectic structure in which mechanical invention seeks minimum effort, and biological invention seeks maximum possibility. The definition and coordination of both is a critical element in Le Corbusier's theory.

THESIS

MECHANICAL ECONOMY: Beneath the apparently chaotic visage of nature there exists an order. This order reveals itself in the process of purification and through the logical interaction of all elements in the natural sphere. Thus the sun and the solar day, as in primitive cosmologies, becomes both the notational and phenomenal arbiter of mechanical economy. As a plant bends on its stalk, following the sun from which its energy is drawn, so man is instructed to reflect the same logic in the cycle of his daily activities. In a quasi-religious incantation, Le Corbusier declares: 'The sun is our dictator'; within the limits of the day which it describes are bound all human activities.

The image of the solar day is given throughout Le Corbusier's writings as illustration of the fact that technology is not license to free will; rather, it is invitation to conscious participation in natural creation. Technology addresses itself to the efficient elimination of human necessity. To direct it towards the production of extraneous and ornamental items is to perpetrate, not mere folly, but a crime against nature herself.

Within the confines of the solar day an economy is to be exacted: the maximization of productive efforts towards the elimination of necessity (necessity presumably as an absolute rather than a relative concept); the creation of free time for the cultivation of body and mind.

The object-theme of organized product, of human liberation, as derived initially from Fourier and Considerant is the 'mobilization of the land'. The mobilization of the land is an exercise in macro-ecology. It is the technological elimination of necessity through the efficient and purposeful utilization of the laws of nature. The recognition of the organized interaction of productive efforts — the logic of collectivism.

On the one hand, nature: a cone opening away from us towards infinity. Its point transfixes us, its constants are always flowing through us.

On the other hand, another cone, also opening towards infinity: human creation.

Between the two cones, where their points meet, stands man. Man the perceiver and man the revealer: the focal point.¹⁵

ANTITHESIS

BIOLOGICAL ECONOMY: The cause of mechanical invention is purposeful; it is the progressive realization of biological potential. It is the image of man released from necessity so as to pursue the cultivation of his body and mind. The dirt-caked laborer transformed into the Classic Greek. In the rendering of a unit from the vertical garden city, Le Corbusier romantically pictures this laborer shadow-boxing on his terrace, an open book resting on a table at his side. He bears a strong resemblance to Marx's liberated man who was pictured as farmer in the morning, fisherman in the afternoon, and critic in the evening.

The freed hours of the day are at once both the great threat and the great promise of industrialization. A surprisingly large portion of *Urbanisme* is given over to the problem of its utilization. In it one pictures the day of man as a pie just so big; if a portion of it is freed, then the issue becomes the utilization of that portion. Hedonism, avarice, and gluttony are seen to advance towards the vacuum left by the condensation of necessity. A tension is desired, an exacting purpose to fill the void. The solution once again rests in the argument of economy. 'Man is purposeful', he sits at the focal point between existence and creation; freedom, Le Corbusier asserts, is not a vacuum, it is an opportunity to create. Each individual is the germinal seed of multiplicity in society; it becomes his duty as a free man to pursue the furthest extent of his own self. The cultivation of body and mind: the spectacle of individualism.

One of the highest delights of the human mind is to perceive the order of nature, and to measure its own participation in the scheme of things: the work of art seems to us to be a

labor of putting into order, a masterpiece of human order.¹⁶

SYNTHESIS

MODULAR CO-ORDINATION: Mechanical economy and biological economy address themselves to two separate issues; the clarification of collective effort and the maximization of individual potential. The co-ordination of both within the frame of the solar day is the theme of *The Modulor*.

Modular co-ordination, which started with a reiteration of regulating lines (a la Blondel) and ended with the publication of *Modulor I* and *Modulor II*, was an effort to co-ordinate construction for mass-production technology, and to insure that such construction would harmonize with both natural and human scales. Thus *Modulor* spoke, not only of the industrialization of building, but to the poetry which lay beyond in the self-conscious re-establishment of cosmic order.

In his journal from India, Le Corbusier writes of the pleasing proportions of a cow. In measuring he discovers that they are modular. While all things were apparently not modular, this example served to show that those which were pleasing — closer to perfection — fall within this system of proportions. Evidently in pursuit of further confirmation of the universality of the *Modulor*, Le Corbusier, when visiting Einstein in America brought up the question of the system. Upon parting the latter is reported to have said, 'You are a wonderful architect, but you should leave mathematics to the mathematicians.'¹⁷ The suggestion apparently did not bother Le Corbusier. Modular co-ordination remained for him the reassertion of spatial dominance over action. Through it, numbers became the ultimate universal; the final abstraction of determinacy; the assurance that phenomena will yield to conscious control.

Mechanical economy, biological economy, and modular co-ordination; the thesis, antithesis, and synthesis of the dialectic of determinacy. The resolution of the collective and the

individual through the spatial. THE PLAN IS THE SYNTHESIS OF IDEAL AND EMPIRICAL FORM.

META-ARCHITECTURE

*I want to fight with truth itself. It will surely torment me. But I am not looking for quietude or recognition from the world. I will live in sincerity happy to undergo abuse.*¹⁸

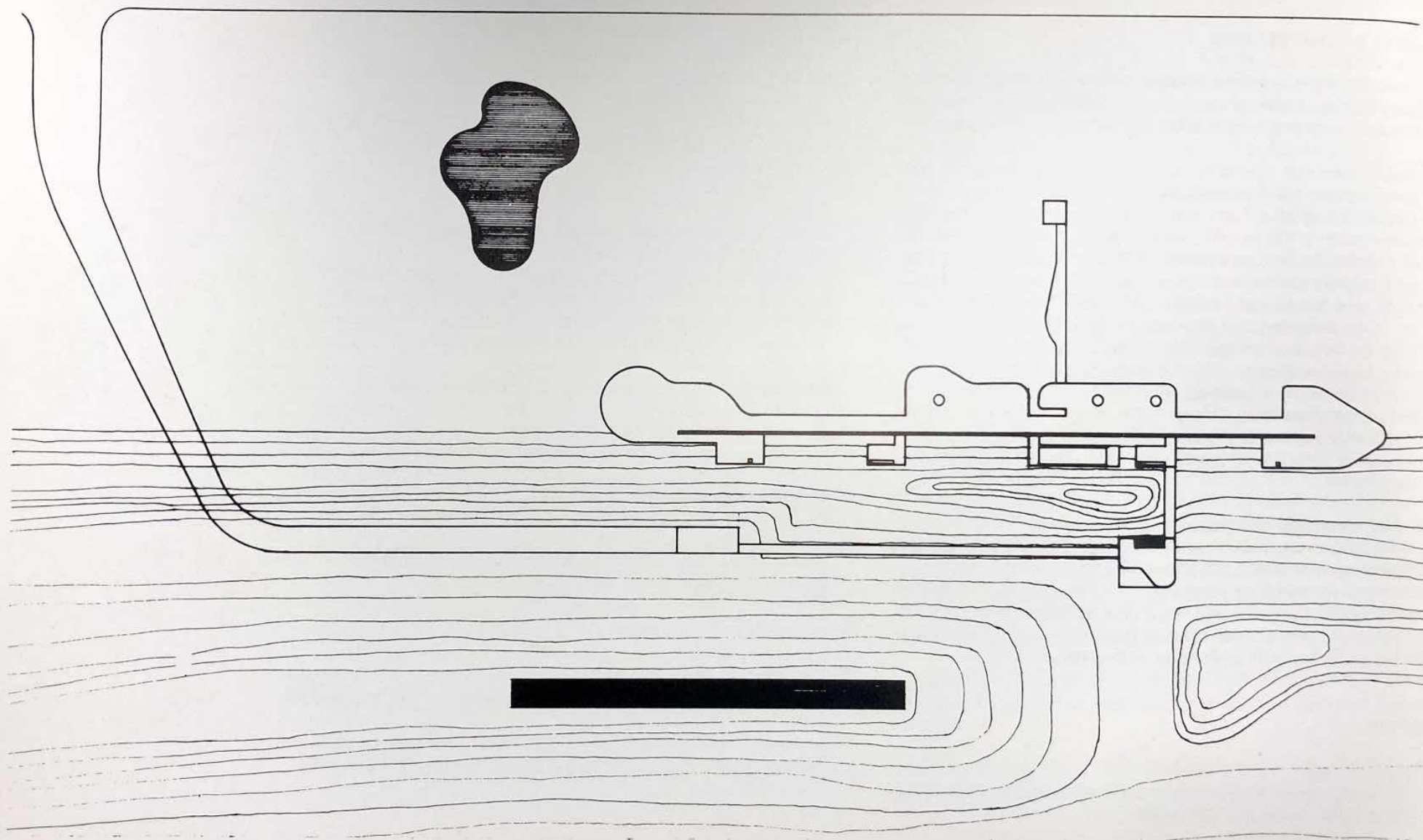
Having inherited the various debates of two centuries concerning planning, the early writings of Le Corbusier are at once both a synthesis of them and a program for their utilization through a lifetime of work. It is somewhat amazing that he could so clearly predict and follow his vision. This foresight suggests that even at the age of twenty-one Le Corbusier might have consciously set out to create a meta-architecture. Yet, even if his efforts were not premeditative, his insistence upon the relation of form to ultimate truth would seem to make its development all but inevitable. In *Purism* the structure of causality is defined; *Towards a New Architecture* — aesthetics; *Urbanisme* — the laws; *Radiant City* — ethics; *Modulor* — numbers. A lifetime's work resulting in the production of an image of man in the universe replete with logos and mythos.

It may be argued that pursuits of the order of meta-architecture are the product of a paranoid or messianic mentality. Yet anyone opened to the poetry of the effort might find its pursuit hard to reject; anyone willing to deem valid questions concerning 'ultimate truth' may find its speculation difficult to deny. If there is to be either a pseudo- or a proto-scientific theory of form, then a way was here opened.

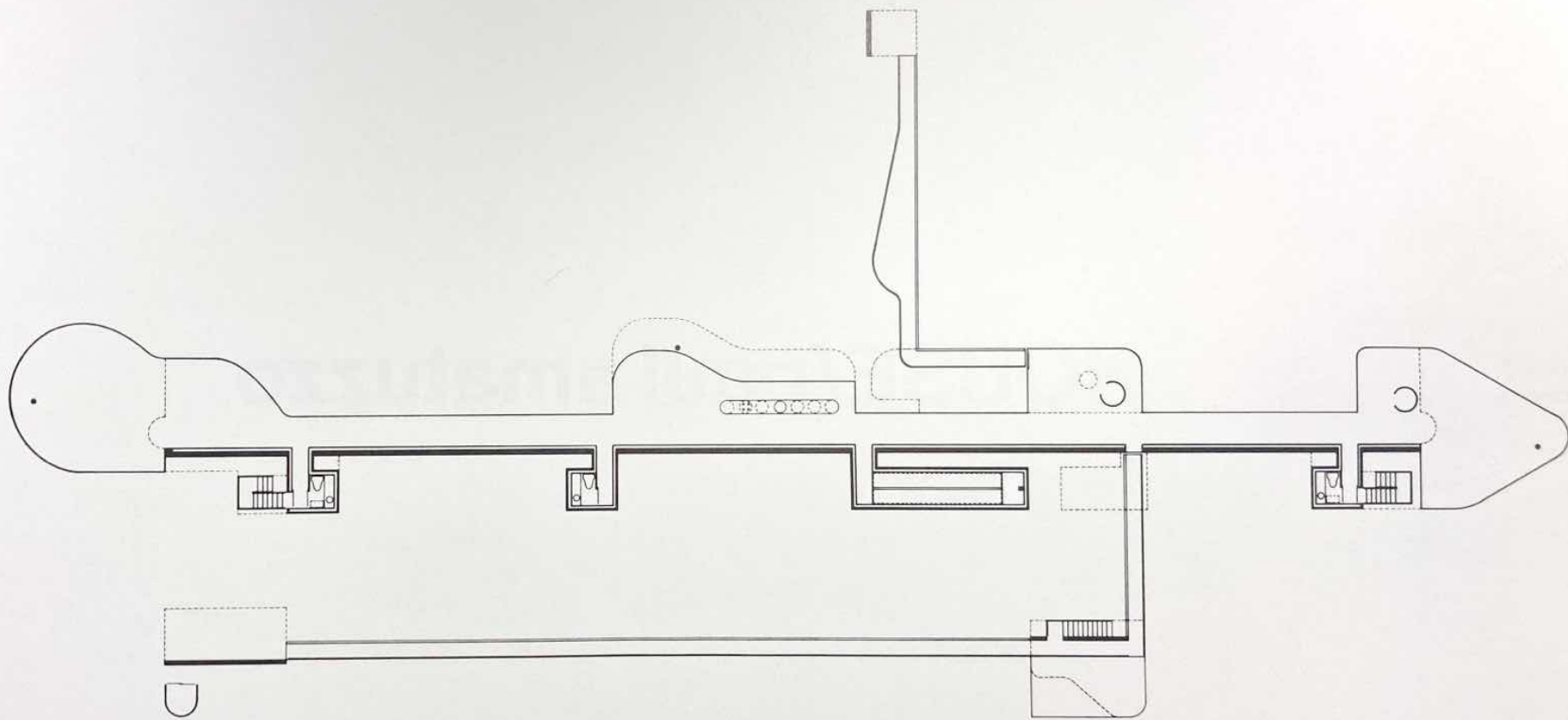
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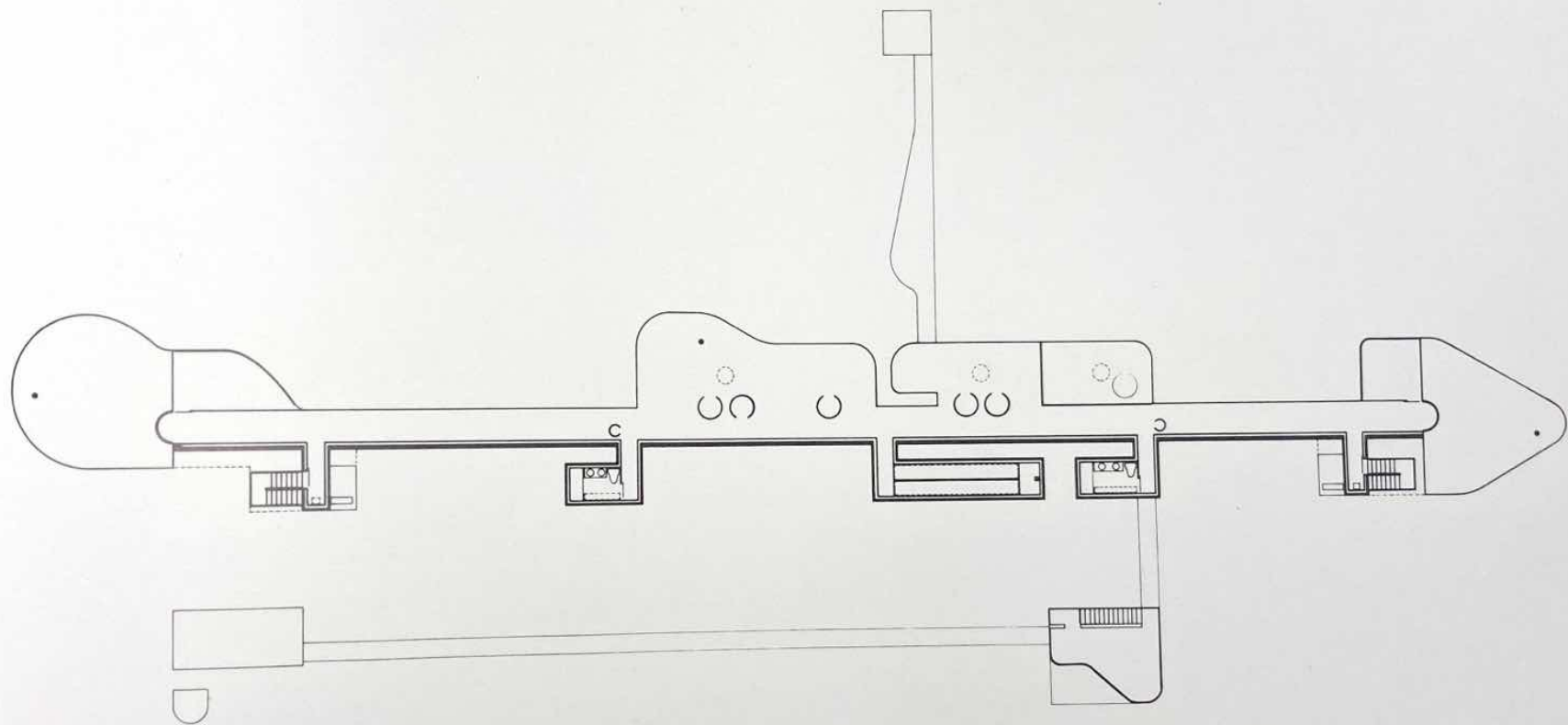
1. Le Corbusier
Towards a New Architecture, trans. F. Etchells.
New York: Praeger, 1927, p.9

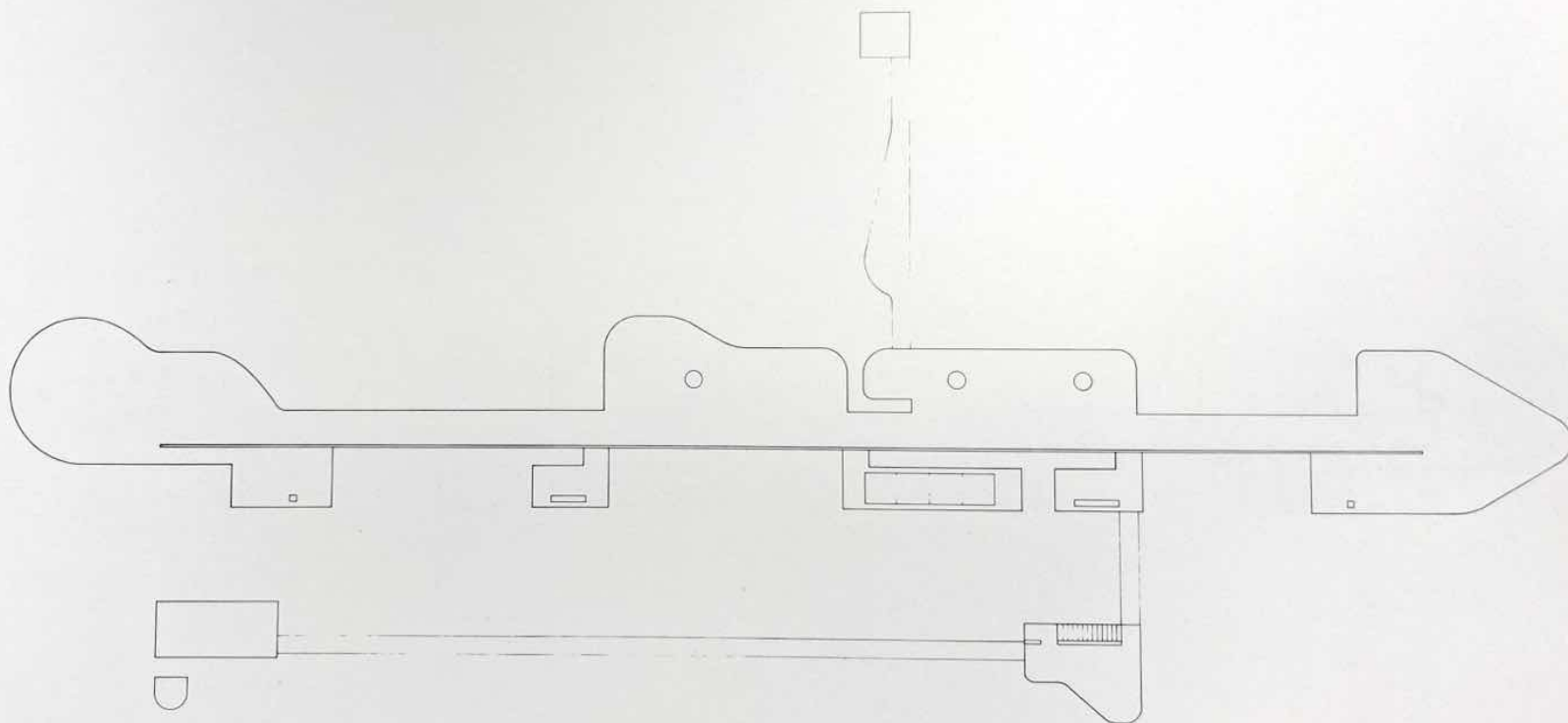
2. Le Corbusier
Precisions Sur Un Etat Present De L'Architecture Et De L'Urbanisme
Paris: Editions G.Cres et Cie., 1930, p.1
3. Le Corbusier and Ozenfant
'Purism', trans. Robert Herbert in
Modern Artists on Art, edited by Robert Herbert
Englewood Cliffs: Prentice-Hall, 1964, p.65
4. For the vitalist notion of evolution see Henri Bergson's
Creative Evolution and The Phenomenon of Man by
Pierre Teilhard de Chardin.
5. 'Purism', p.61
6. Le Corbusier
The City of Tomorrow and Its Planning, trans. F.Etchells.
New York: Payson and Clarke, 1927
7. 'formalistic' here refers to the type of system which projects and evaluates action in terms of spatial frames and components rather than in terms of guiding principles or 'heuristics' — see Boguslaw, *The New Utopians*.
8. Freud
Beyond the Pleasure Principle and Civilization and Its Discontents
9. *Towards a New Architecture*, p.268
10. To a degree, this notion parallels McLuhan's concept of 'suspended judgement' — the anticipation of the numbing effect.
11. *Towards a New Architecture*, p.12
12. Ibid. p.289
13. Le Corbusier
The Radiant City, trans. Knight, Levieux and Coltman
New York: Orion Press, 1964, p.76
14. 'Purism', p.63
15. *The Radiant City*, p.83
16. 'Purism', p.61
17. The meeting between Einstein and Le Corbusier was arranged by Paul Lester Weiner. The story is related by Richard Bender, a partner of the late Mr. Weiner.
18. From a letter dated November 22, 1908 which appeared in the periodical 'L'Architecture d'aujourd'hui' no.51 Nov. 1965.

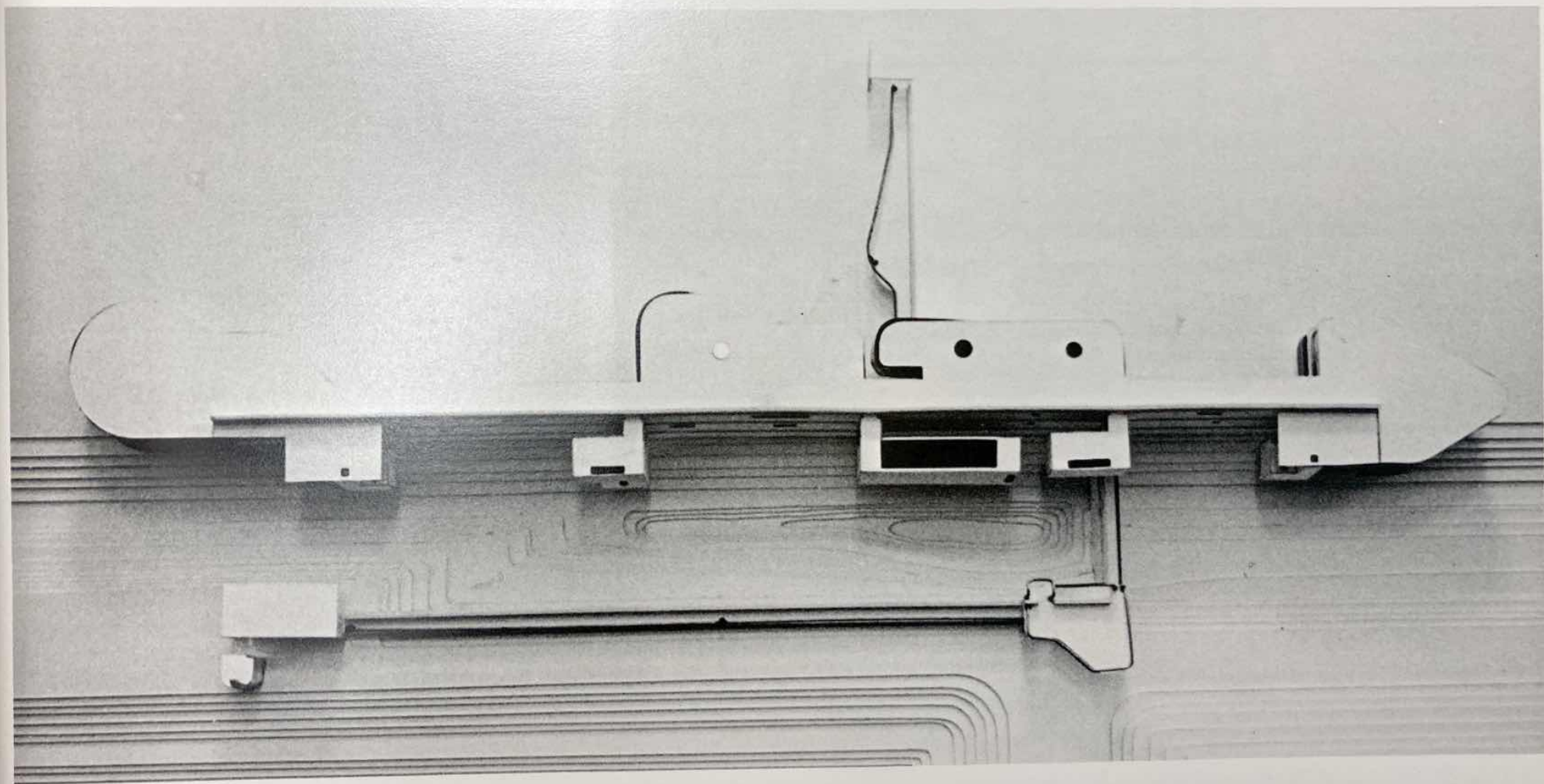


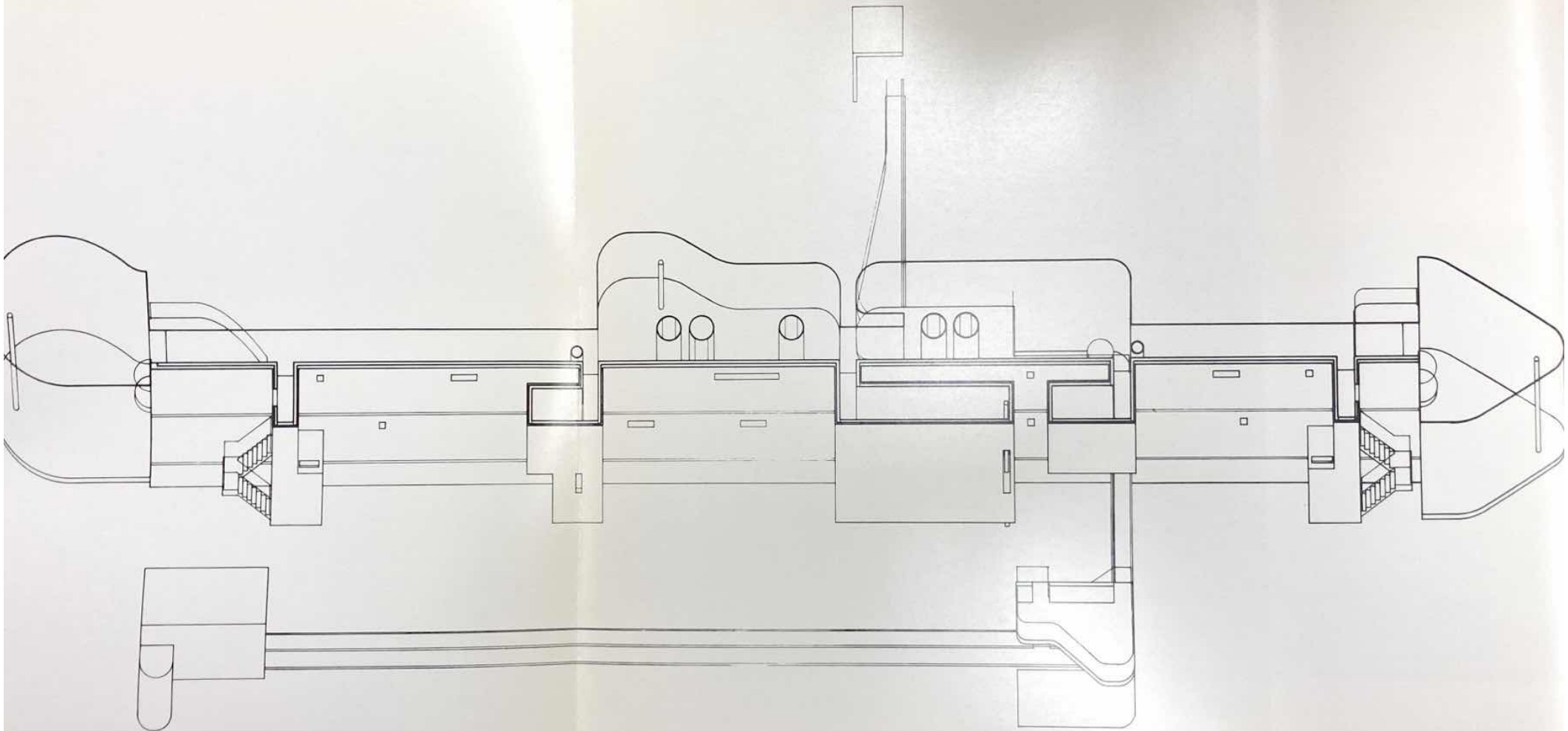
HOUSE/paul amatuzzo

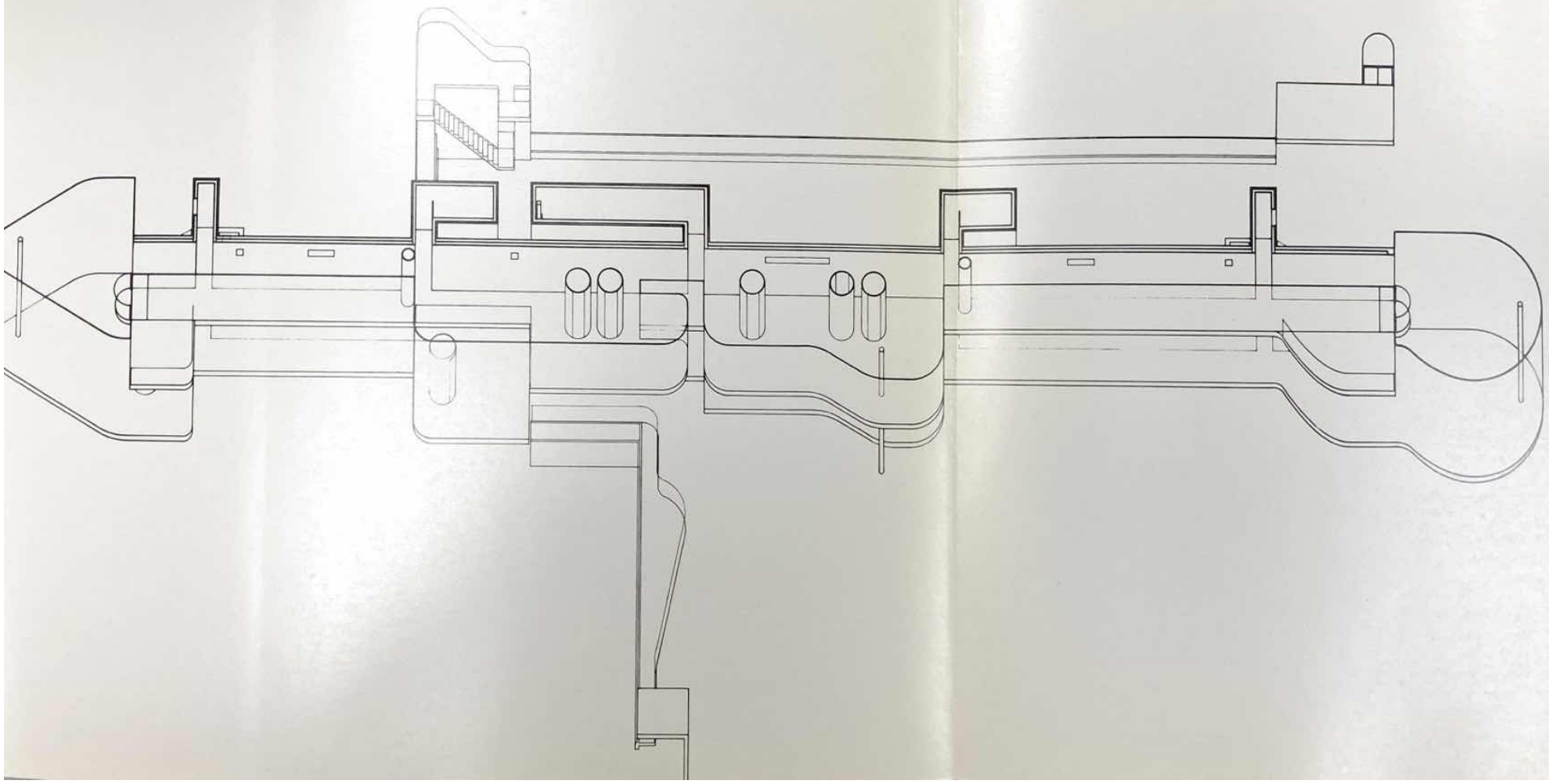


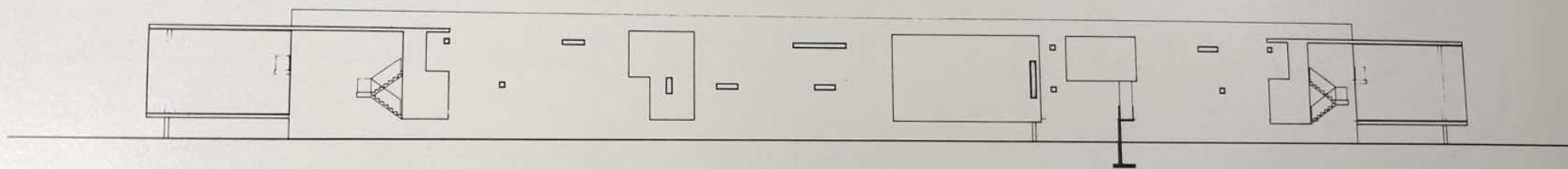


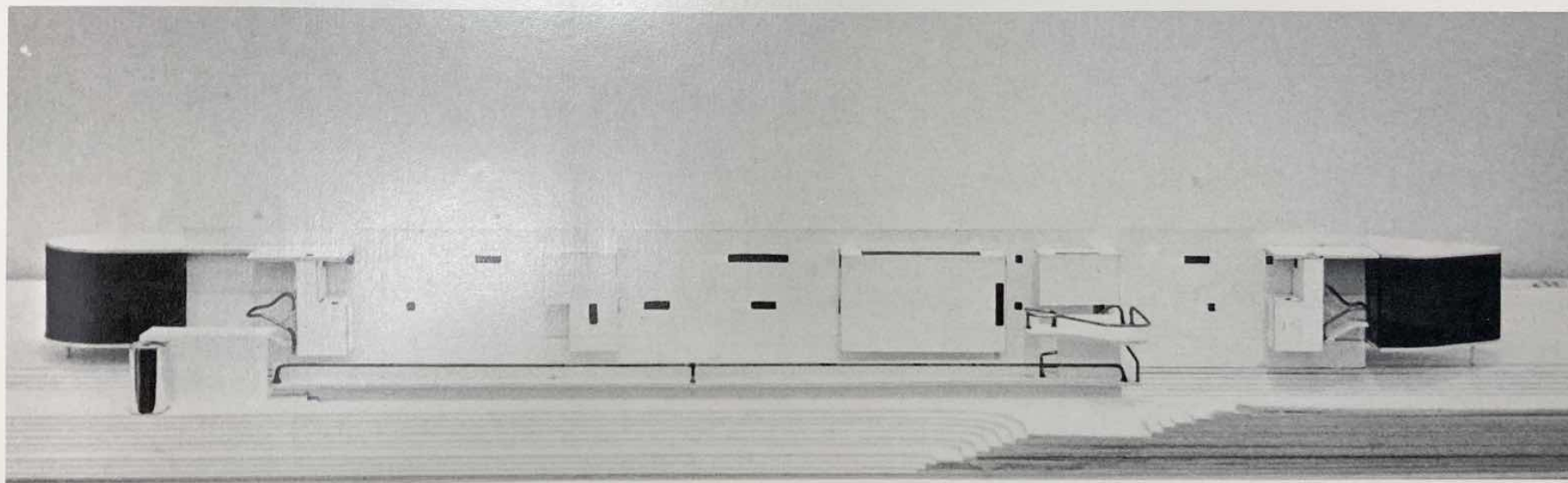


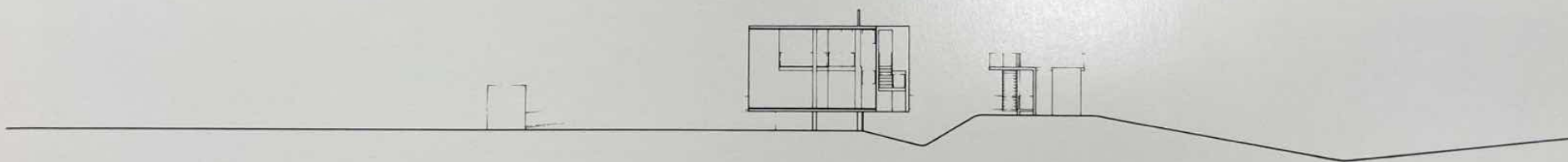


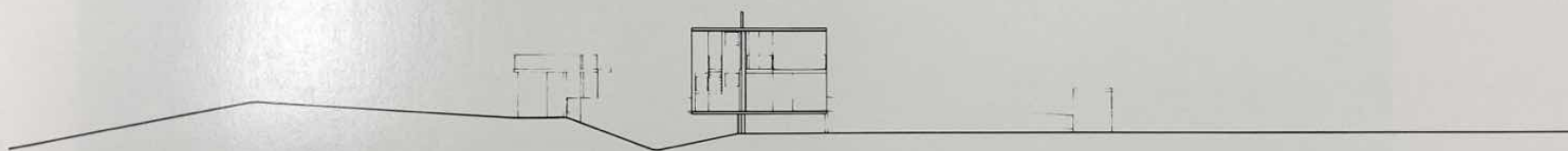


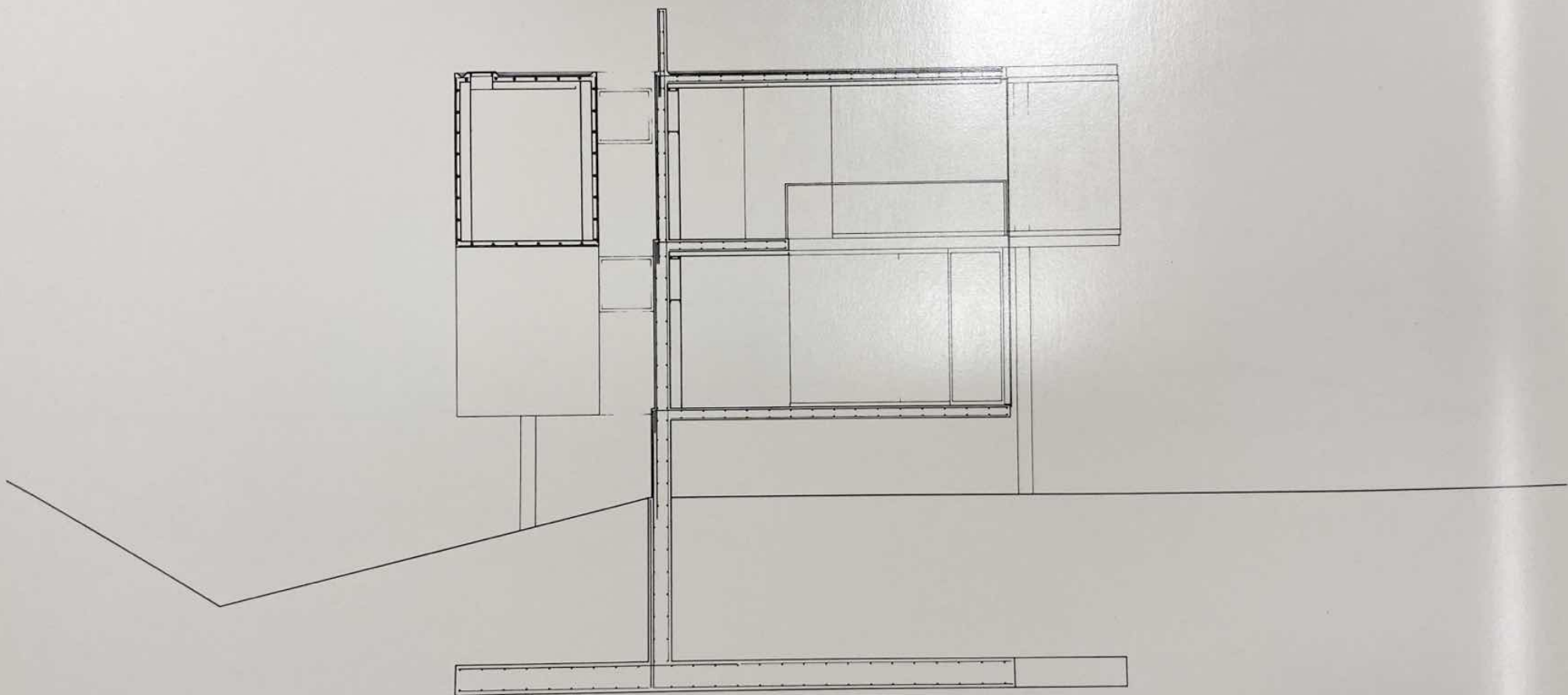


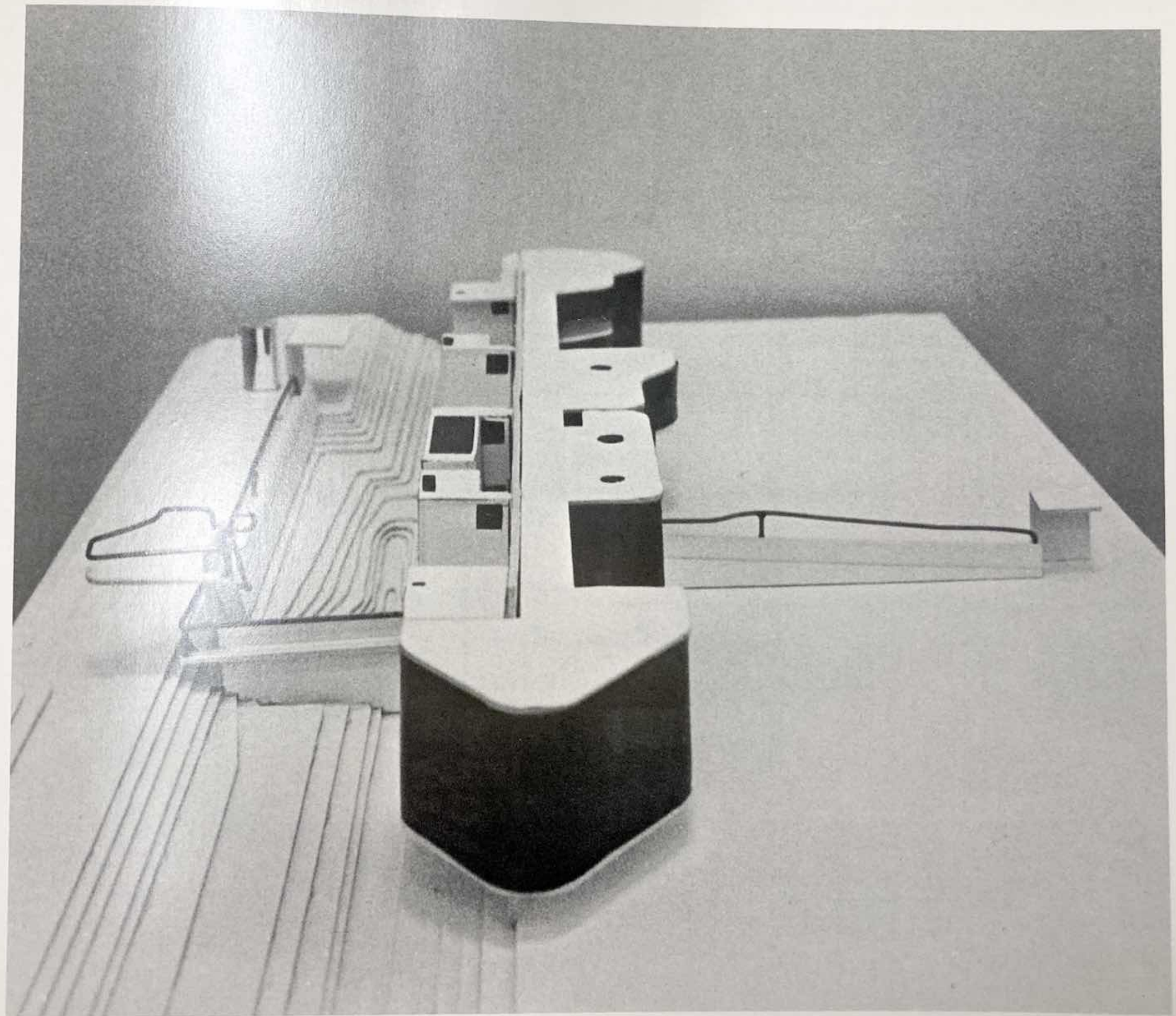


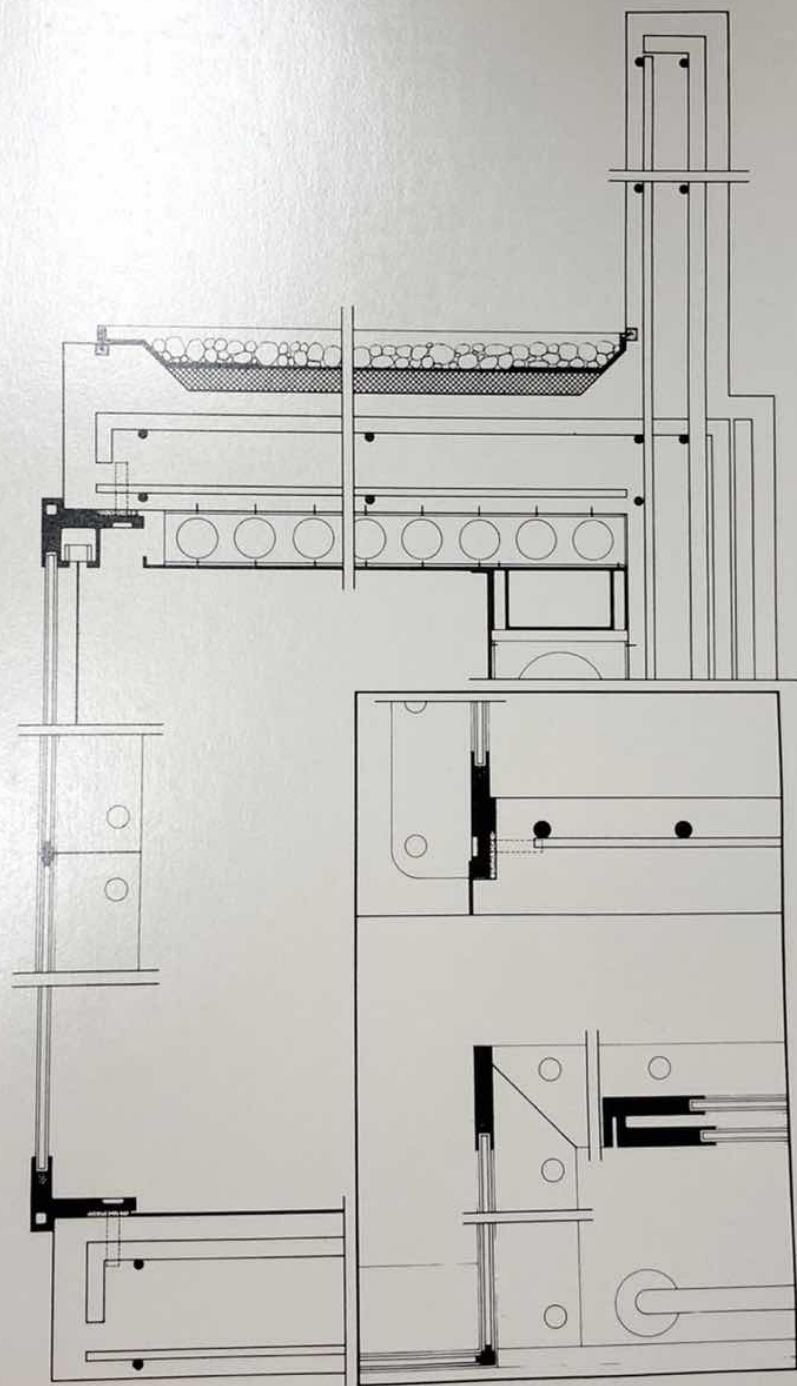


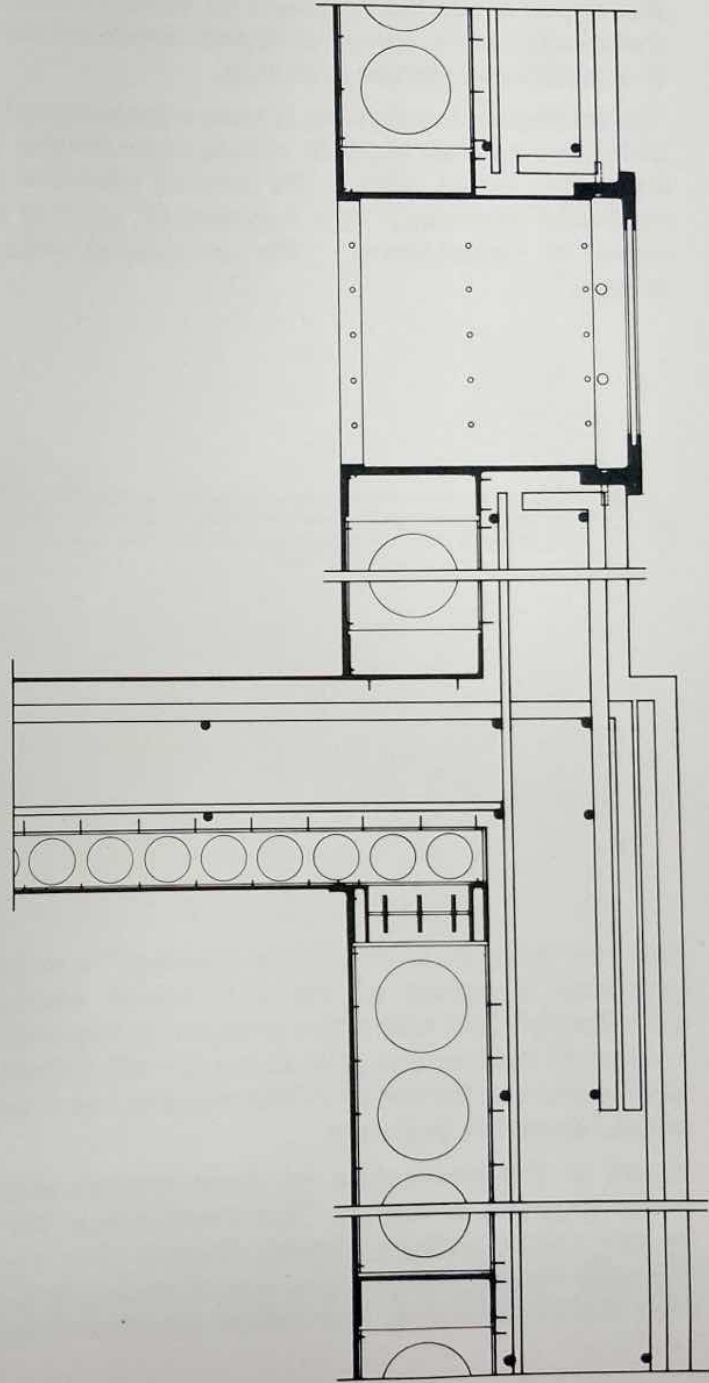






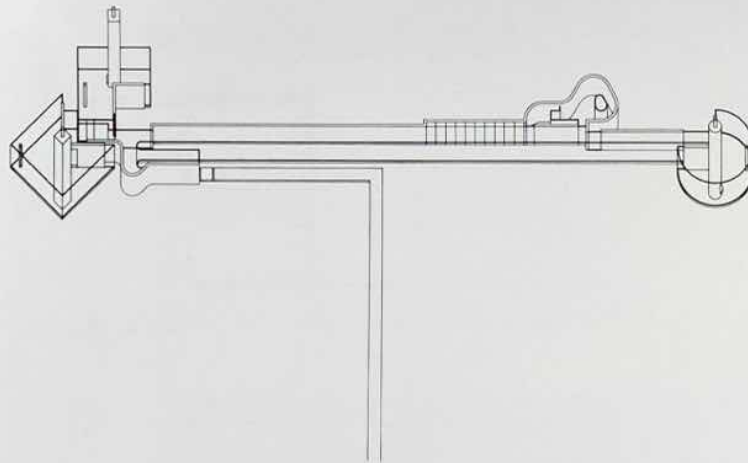






In an age where historical and formal precedent is held suspect, it is perhaps necessary to make an affirmation that there exist certain formal constants which are the generators of a continuous creative evolution.

The accompanying drawing is from a project produced in the spring and summer of 1968; whose initial scheme was shaped during the fall of 1966 in the form of what one called "the horizontal extension," "the hypotenuse" or, in the very early stages of development, "the centralized relief upon a tableau."



Now the "centralized relief upon a tableau" is not an entirely fortuitous extension of the architectural vocabulary; the ideas incorporated within this proposition began to emerge in a series of lectures one gave at the Cornell School of Architecture and the School of Architecture at the Chicago Circle campus some five years ago.

It was in the preparation for those lectures that a certain theme began to crystallize. This theme was in fact explored by the Cubist painters Picasso, Braque, Gris and Legér in the early part of our century, and which, shortly thereafter, drew the attention and maintained the interest of the archi-

tect Le Corbusier in the magnificent creations of The Cité de Refuge building of 1929-33 and the Swiss Pavillion of 1930-32.

These buildings have always intrigued one. In the case of the Salvation Army building, a group of volumetrically small and varied shaped pavillions are placed before a flat tableau facade of glass made up of a gridded glass frame. The Swiss Pavillion works in a similar way, if a bit more complex.

One might infer that Le Corbusier was manipulating two major compositional themes; that is, the play between the bio-morphic and the bio-technic. The predisposition is towards the bio-morphic in the entry pavillions and towards the bio-technic in the gridded, glazed, and evenly modulated tableau-facade. The juxtaposition of these two themes represents a particular condition of modern architecture; the one, the technological precision of the high rise tableau-facade; two, the spatially oriented pavillions placed near the grade and near to man.

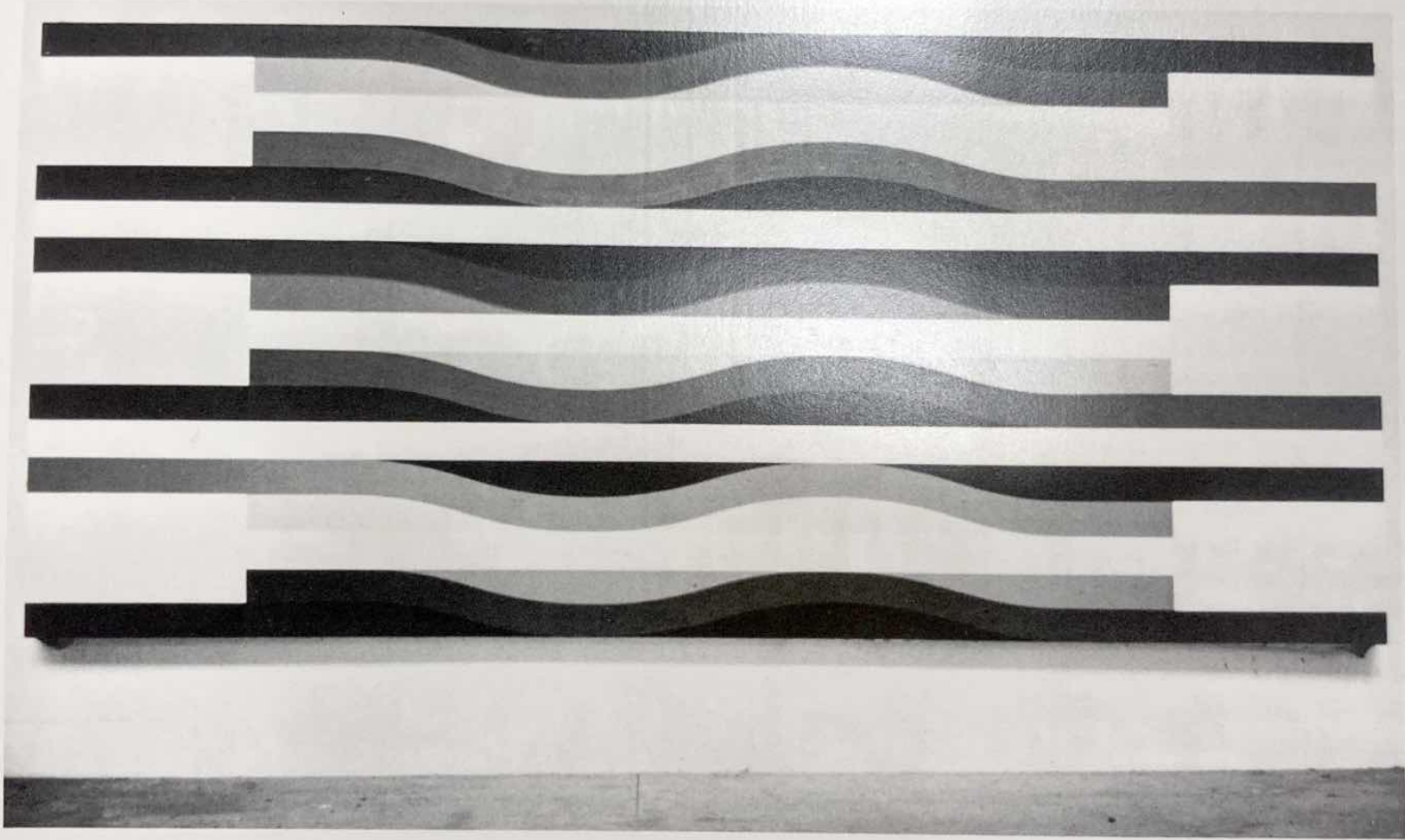
It became apparent that several of the Cubists, in particular Gris and Leger, operated within a similar field of ideas. A correlation of the interests of the architect (Le Corbusier) and of the painter (Juan Gris) or for that matter Legér, were not difficult to make.

Now what has all this to do with the drawing of the presented projection—it is precisely these ideas that have informed this project and that have been utilized as the generative forces for certain of the didactic and exploratory problems given our students in their final year.

During the past years, Professor Slutzky and I have been setting up specific problems and lectures oriented towards the major formal themes of an Architectural and painting heritage in order that a formal leap can occur. I take the responsibility of introducing the problem of "Do a building in the intention of Juan Gris." This has horrified many, turned off some, interested some, turned on a few, but because of the nature of the inquiry other areas of investigation have opened up; and this is what one calls the educational process, a process in which private property becomes public.

— John Hejduk

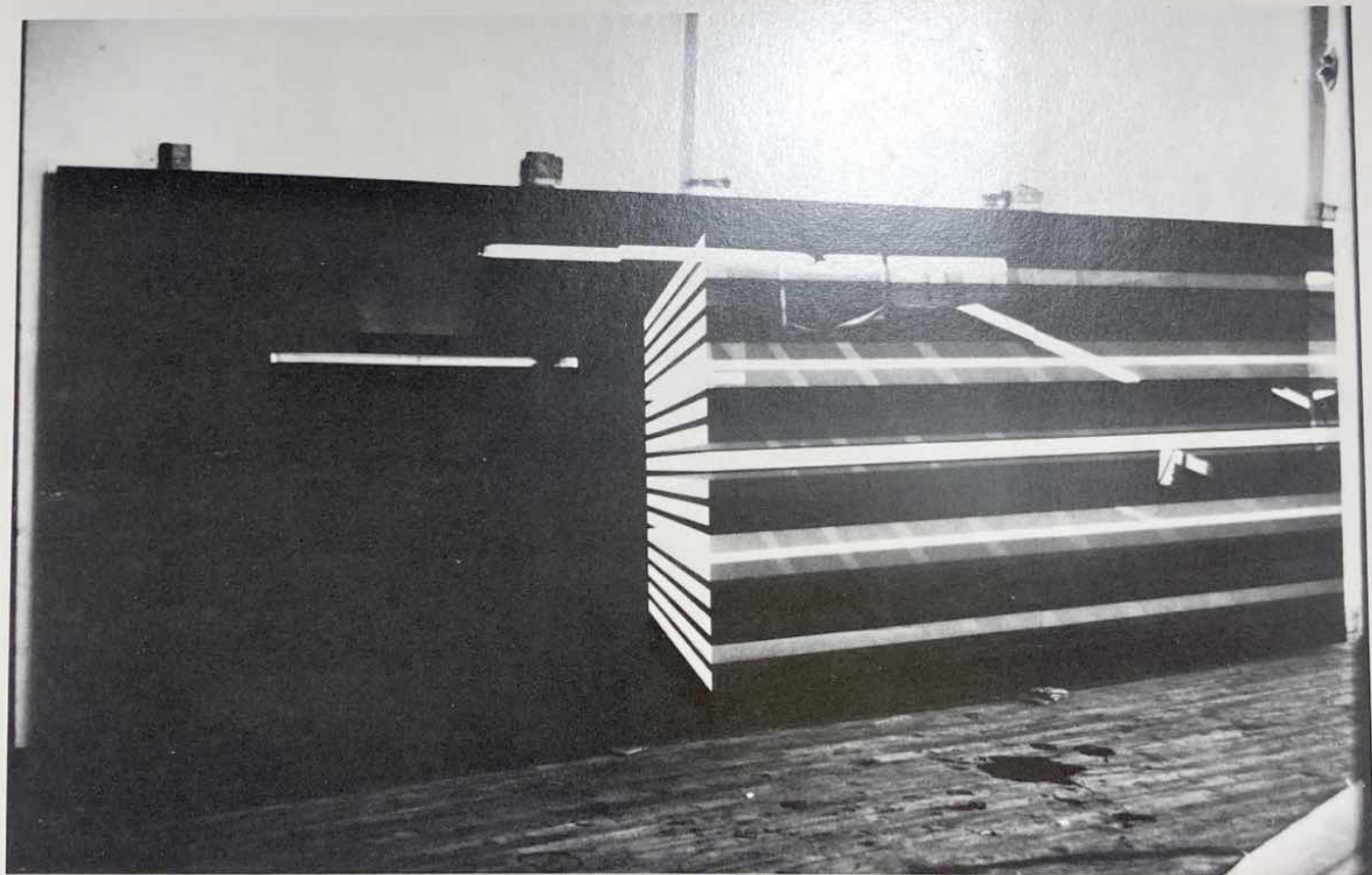
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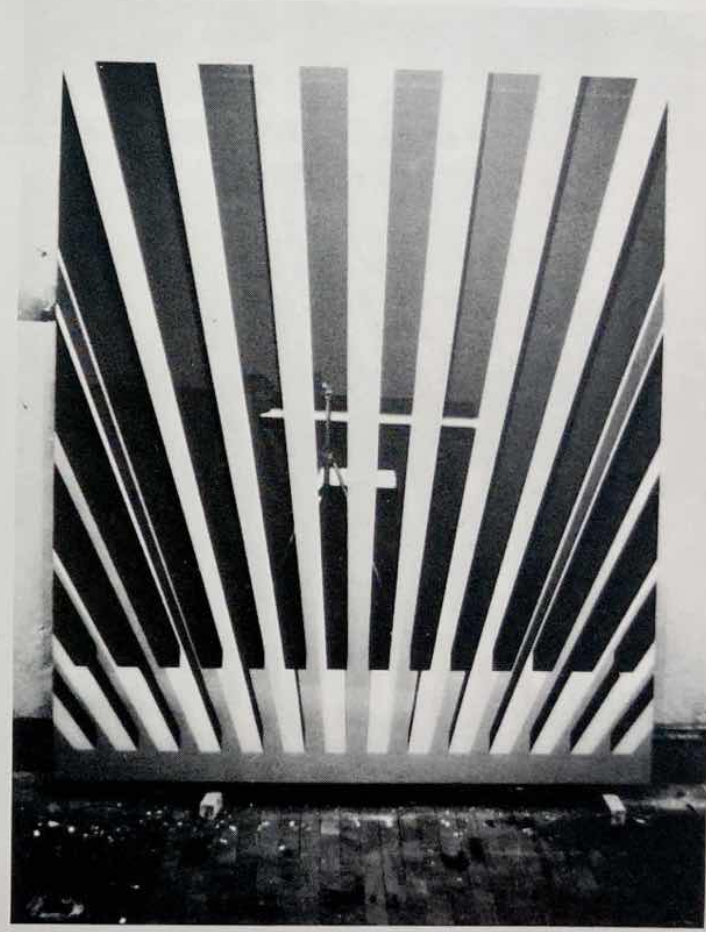
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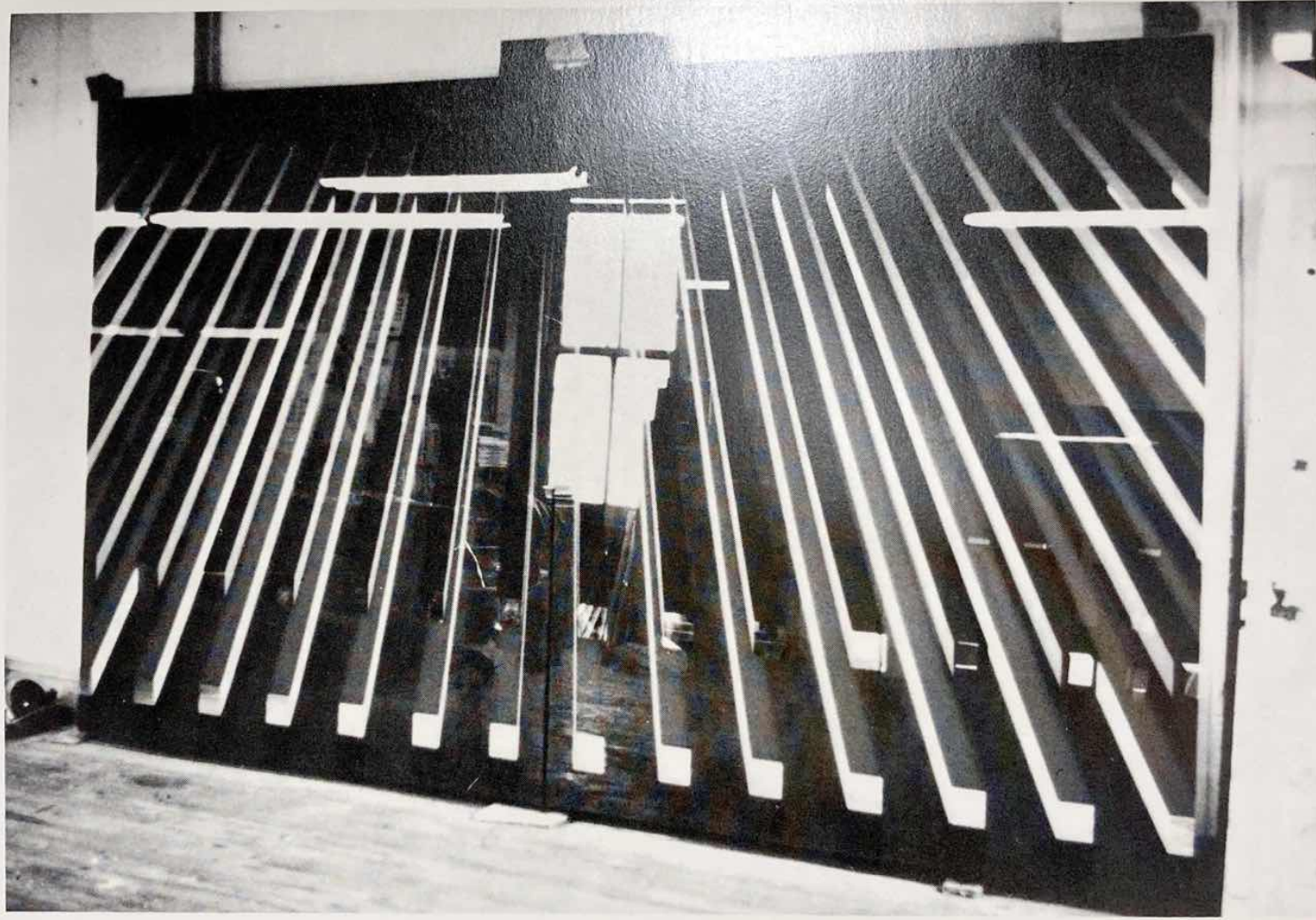
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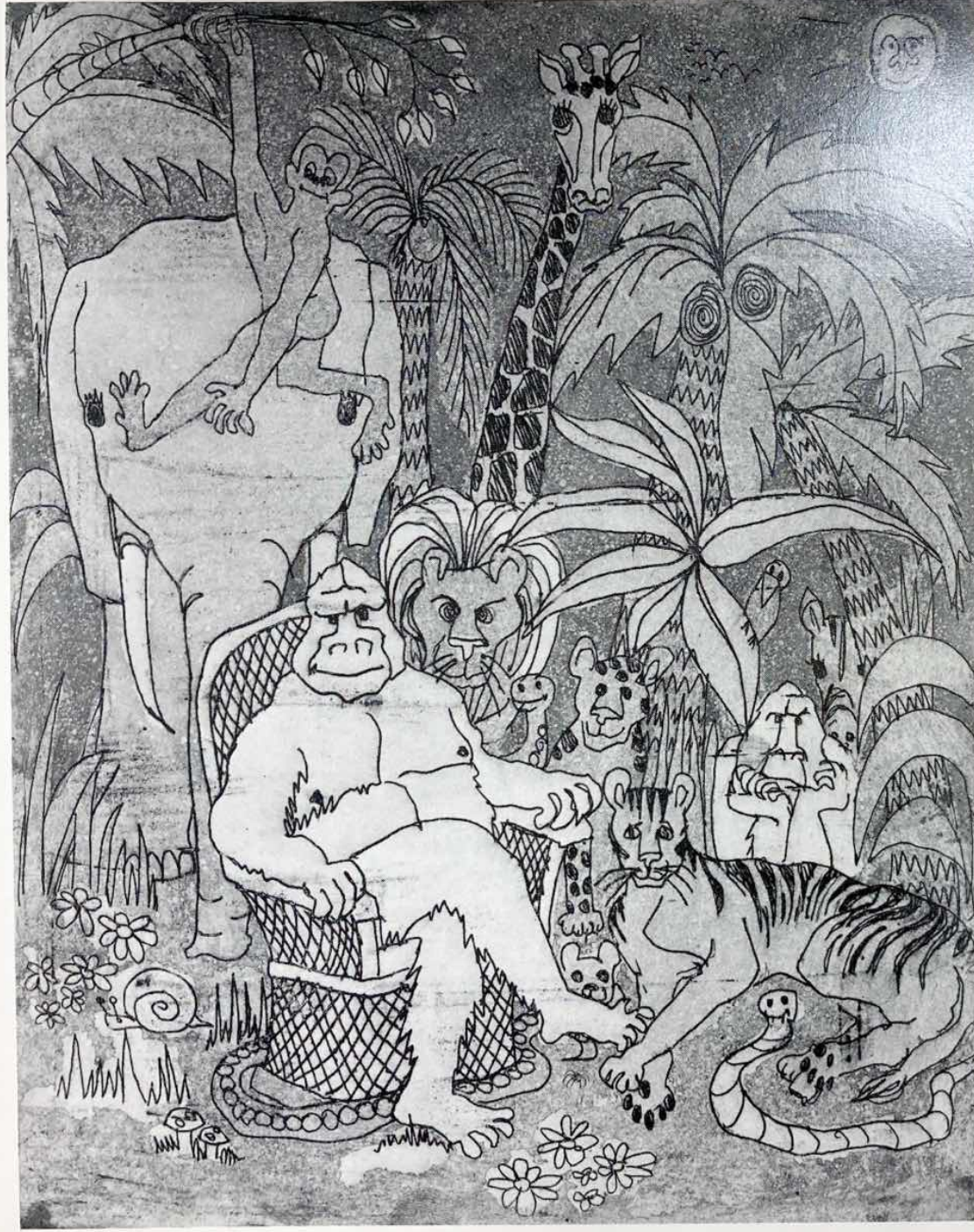
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RICHARD ROTH



ERICKA HAMBURG

OUT OF TIME AND INTO SPACE

JOHN HEJDUK

Art has that peculiar irreverence towards accurate chronological sequence. It hops backwards and forwards upon the frame of time, playing hide and seek with the Historian's sense of propriety. The perennial stylistic arguments which cause the investigator concern will only bring forth mild amusement to the creator and critic of form. The event is important as a relationship to other events, particular not to time but of space. Therefore, Le Corbusier's Visual Arts Center at Harvard proves the staying power of a single idea; the idea of cubist space in Architecture.

The very profundity of this piece of visual metaphysics brings into question all that went before. The Carpenter Center can either be liked or disliked — this is irrelevant; the fact is the proposed ideas cannot be ignored; they can be viewed squarely and understood. The questions and arguments become inexhaustible; they are like the major thesis — the thesis of simultaneity. Simultaneity has always been a complex phenomenon with reference to the retina's capability of maintaining hold over kaleidoscopic relationships. The mind may be more prone to accept an ambiguous basis, yet when operating upon single stills, the eye is like a camera; the moment the same image is clicked twice and interposed on the same frame an interesting effect can be obtained although in the process the initial form becomes blurred and might be irrevocably lost.

The human body, its auxiliary senses, and the capability of cerebral workings cause architecture to be involved in the movement and dynamics of space. One cannot approach the Center without unleashing the ghosts and spectres of the visual revolution which occurred at the early part of our century. Old doors are forced open admitting Picasso, Braque, Leger, Gris, Mondrian — all the known protagonists and ancestral impregnators.

To begin with, the disposition of building to site may seem erratic, uncalled for, in opposition to the hieratical laws of good taste, particularly when the work is tipped and askewed at an acute angle to the sensibility of right-angle relationships of the two streets and two buildings it is enclosed within. Surely, most of the buildings on this street had the good sense to present their best facade forward. Why does the Frenchman insist upon disturbing our puritanical attitudes? Is it effrontery or whimsy? It is neither; it is a reinforcing for all concerned. The sense is on two planes of operation, the external and the internal. The external ordinarily precedes the internal; here at the Center, they are co-joined to the same organic system.

There might never be a compatibility of Cubist vision with New England decorum. The problem was not how to relate them, but how to disengage them, permitting each its sovereignty. This is what Le Corbusier has accomplished; not only did he placate his neighbors, he also used them in the scheme of things. A system of co-existence was devised through the askewing of the Center. This was a secondary reason, the primary being involved with a Juan Gris-like disposition of 90-60-45-30 degree griddings and their spatial implications.

A square, when tipped at an angle of 45 degrees, loses its previous static orientation. The four corners immediately become charged and filled with maximum tension. Piet Mondrian was aware of this phenomenon. Le Corbusier is cognizant of the tension ramification. When Le Corbusier moves the major central loft block upon an angled axis, the corners simply become taut and activated. The attention given to these points fixes the disorientation.

As a scholasticist, Le Corbusier realized it is too simple just to present thesis. The anti-thesis had to be propagated, thus the curvilinear shapes (Figure 1a, b, c) at the periphery, juxtaposed in shear, act as half wing-screws to the central configuration. From the exterior these bulbous locks compress the central block and re-establish an implied right-angle relationship to their associates. The split, sheared, turned about mandolin, is the external transition between two combatants and smoothes the way for the acceptability of the transient intruder. These are the social soothers of the retina. An observer's eye is constantly ricocheting off the outer surfaces of the Fogg Museum and the Harvard Faculty Club back again to the Center. The eye never attempts to relate the two — it never has the time — it must focus on one or the other, but never on both together.

At first the somewhat agitated contour of the building can come as a shock to the student of our long-ago rationalist. Upon closer look we see the old principle of contained field in operation. The parallelogram figure is completed by implication. The beginning points of the major entry ramp make this necessary completion. The generating nucleus of the cubist scheme is the inserted 'Z' bar which moves through the center providing for centrifugal acceleration. The ramp is in three-dimensional torque, it is the aorta of the heart upon which the breathing depends. Like a bicycle pedal, when pressure is brought down upon the terminal ends, the whole building starts to revolve and spin. The curved blocks are the governors and screws — tightening, loosening —

FIGURE 1a

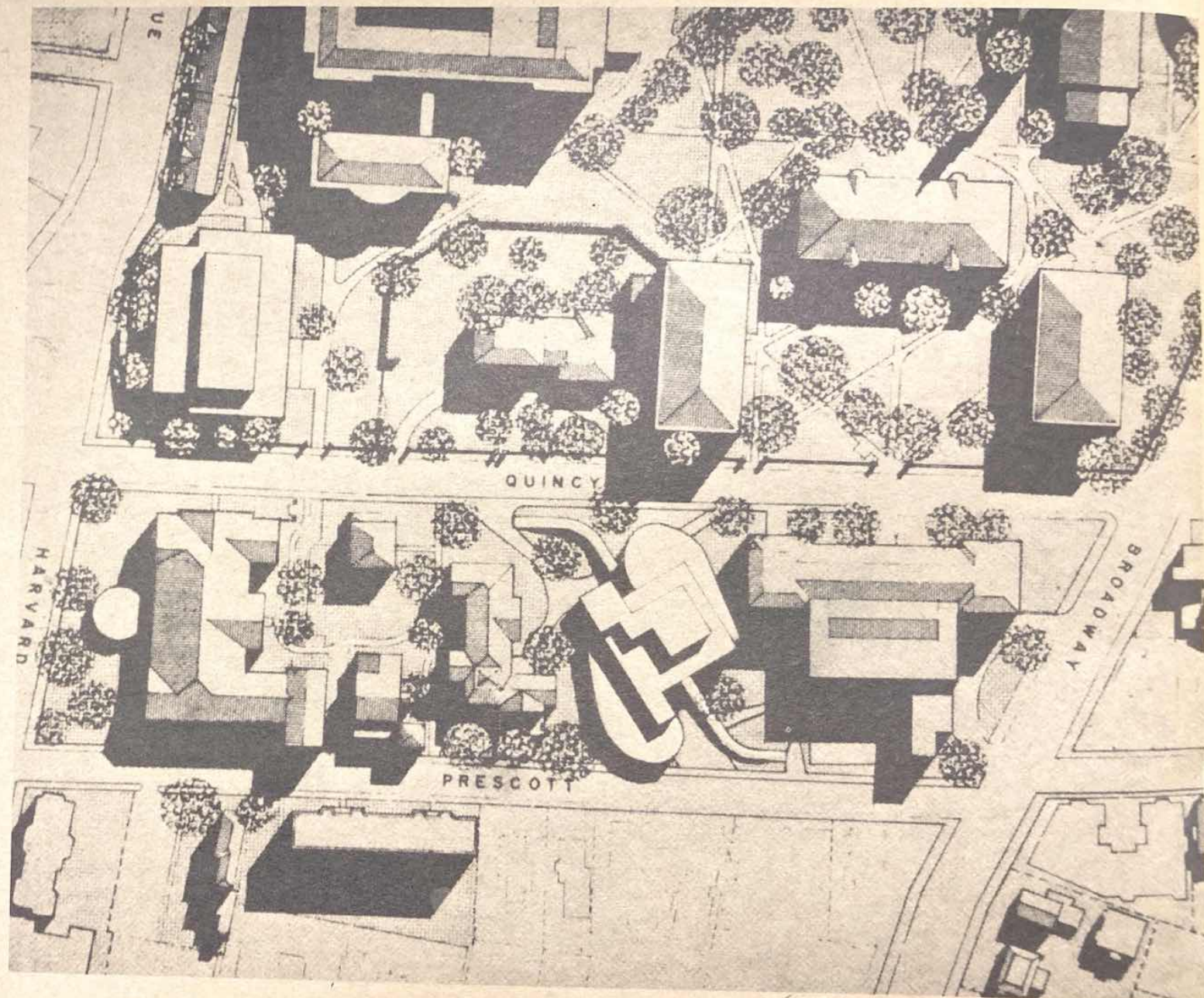


FIGURE 1b

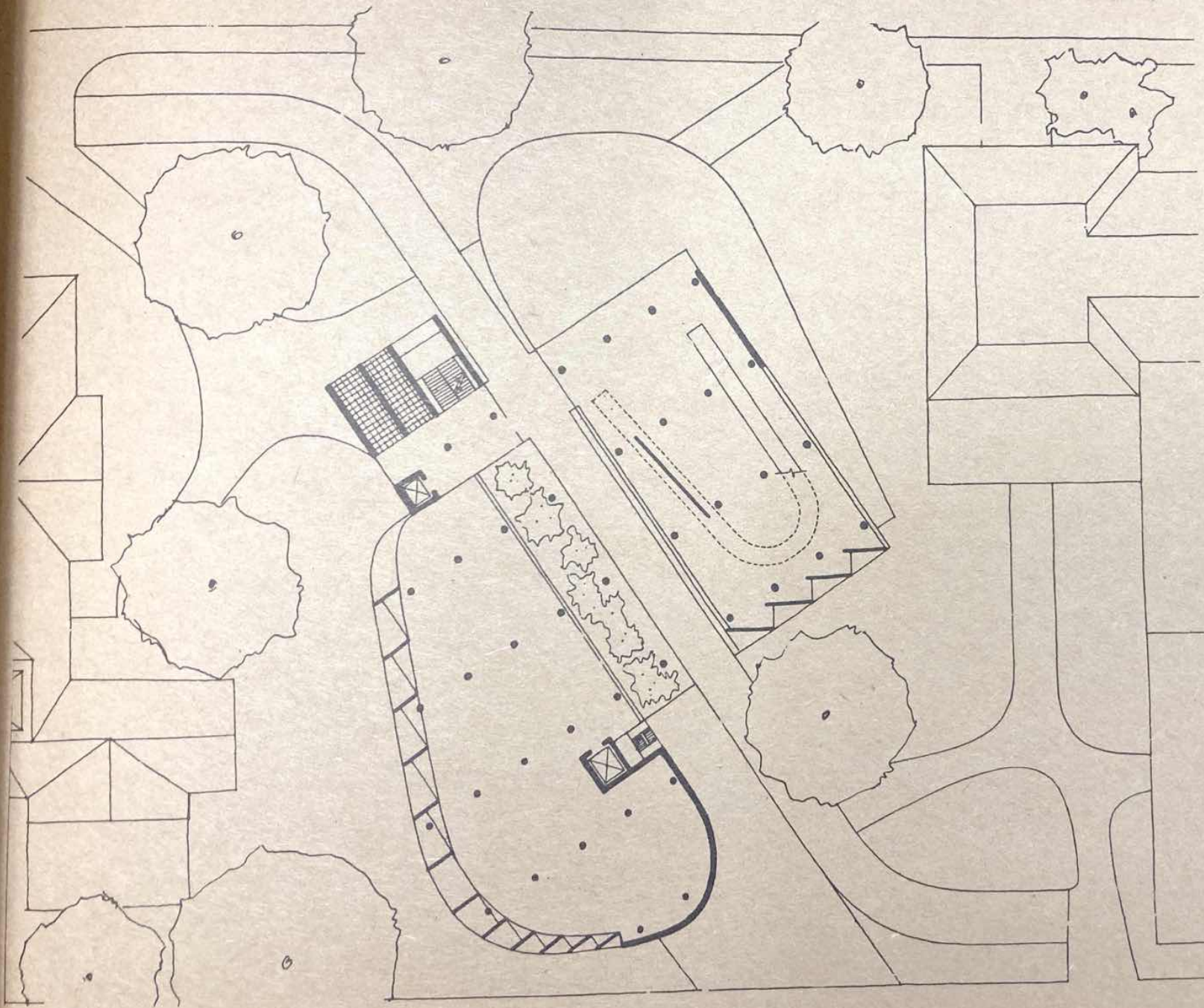
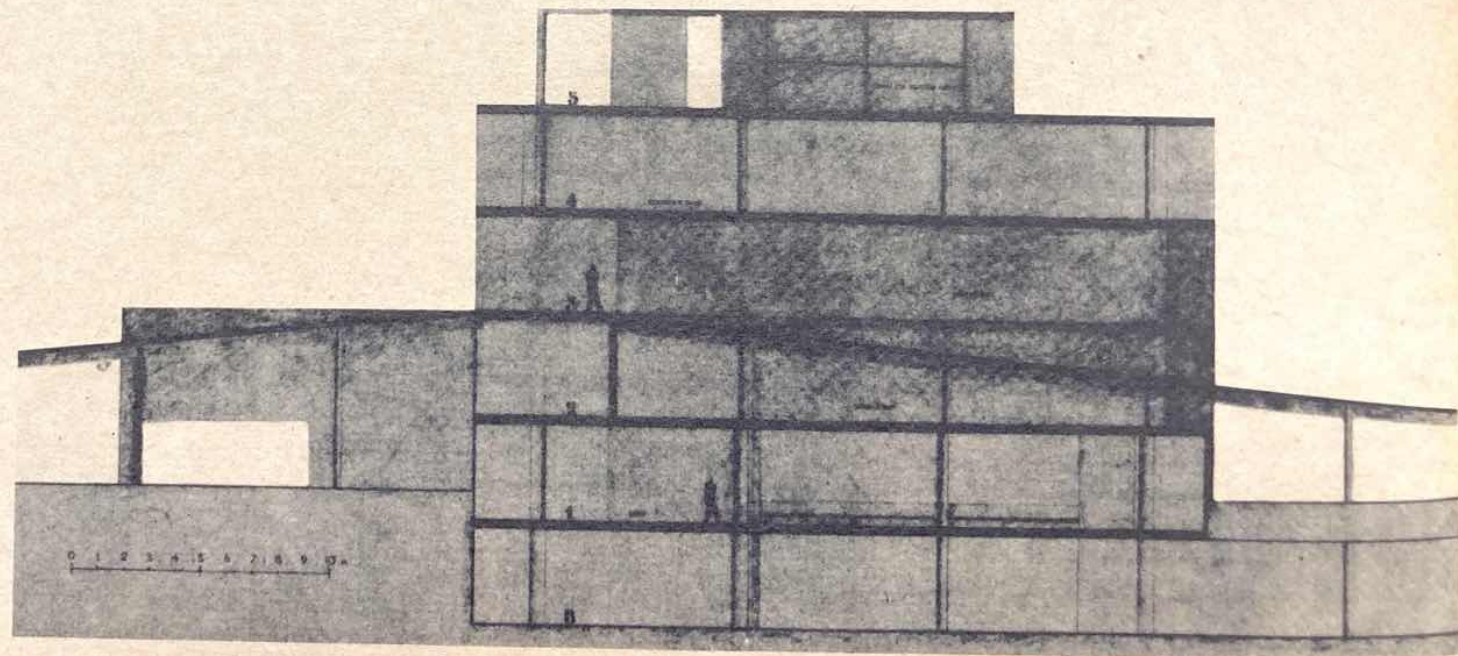


FIGURE 1c



the run-away spatial fantasy.

The site is finished off in a network of walks and warped grade planes. The axial views upon the ramp terminate — one to a Jacksonian portal; the other to a Bostonian misfit. The way for the central theme is now prepared.

In order to fully understand the implication of spatial views incorporated within the Center, one must look at the workings of the Cubist canvas; in particular, the synthesization by Juan Gris (Figure 2). The architectural ramifications are answers to the new Center's mysteries. Before entering this sacred field, it is in order to say that the ideas scattered throughout the Center have been encased within a time-bomb set in Paris during the early 1920's, and finally exploded at Cambridge, Massachusetts in 1963. The detonator did not realize that another bomb was fired with a smaller, stronger, and more devastating discharge in the form of Le Corbusier's *Villa Garches* (1927, Figure 3), and Mondrian's *Victory Boogie-Woogie* (1943, Figure 4). Perhaps it is necessary to throw bombs back into time in order to effect a future liberation. Since the first setting, the dialectic has continued with painstaking exercises and fulfillment upon the canvases of Piet Mondrian.

Le Corbusier is well aware of the Cubist and the Neo-Plasticist points of view. His architecture is the pendulum between the two poles of spatial magnetism. Today the weight seems to be in favor of the Cubist vision; although the seduction of the spartan, flattened, taut, shallow depth formulation[†] holds its grasp. *Villa Garches* was the pinnacle of the Cartesian instigator; it remains the classic contender in the new world of architectural space.

The Cyclops of brute force is again challenging. The stimuli for further spatial conflicts exist.

† **Perspecta 8** — Yale University Architectural Magazine. 'Transparency' by Colin Rowe and Robert Slutzky. Professors Rowe and Slutzky present a remarkable study in depth on the subject of flat space in Architecture.

The composition entitled *Guitar, Glasses and Bottle* by Juan Gris (1914, Figure 2) will be used as a prototype for investigation. *Violin and Newspaper* (1917, Figure 5) can equally be viewed as a generator.

The field comes first. As with most Cubist canvases, the field worked upon is usually directional; it either has a vertical or horizontal preference, perpendicular to the observer's vision. In the above paintings the field is vertically disposed. Rarely did the Cubist use a square canvas. The foundation had an *a priori* directional orientation. In contrast, the canvases of Mondrian are usually square; a non-directional field. His first bias is one of equilibrium. The Carpenter Center favors the Cubist vision of field.

The major planametric direction of the building is reinforced by the ramp and structural bay disposition. The long bay runs parallel to the ramp; the short bay perpendicular — therefore introducing compressed spacing and tighter penetration (Figure 1b).

Guitar, Glasses and Bottles, as well as *Violin and Newspaper*, are split through the middle, with a vertical and horizontal axis dividing the canvas into quadrants.

The shapes and figures congesting the inner field energize a high concentration of action towards the intersecting axis, compressing the central space. The compression eases off as the eye is lead to the periphery of the canvas. It is as when a stone is thrown into the water — upon disturbance of the surface and depth, the radial forces from the point of contact outwards diminish in intensity with the distance from the nucleus of impact. Le Corbusier's plan of the Carpenter Center is presented in a similar manner, with one important difference. This difference is the edge compressor which imposes itself on the free flow of space regarding the peripheric boundaries. Le Corbusier splits the scheme along the longitudinal axis creating a high concentration at the center of the form through the use of the ramp, the major entry ways, and the vertical-horizontal circulations. As one moves away from the necessary biological nuclei and organs, the space flows generally un-interrupted until it arrives at the edges where again it is activated through the forms of curved walls, 60-30 accordian-like brise-soleil and the horizontal syncopation of the vertical mullions. The peripheric tension is homage and acknowledgement to the Neo-Plasticist contribution. The push-back of the forces to the center establishes the spatial fluctuations.

A plan is a section — and when sections are put together they make space. If Le Corbusier is interested in the phenomenon of the flat plane in plan, it could follow that the vertical sections might operate in a similar way. Upon close look, one finds that they do. Le Corbusier is involved with the co-ordinates of spatial composing. As with the plan, there is a high concentration of elements in the center of the sectional configuration. The elongated slot through which the ramp passes is the locking device for the two curvilinear volumes. (Figure 1c). These volumes act in shear, pulling laterally in opposite directions towards the periphery. These are capped and compressed in a sandwich vise of the upper and lower floors, applying additional pressure to the centralization of space. The same generator works both in plan and section. Given all the necessary plans and sections, the cubic configuration is set into motion driving the whole organism around the field of space.

The constant rhythmical modulation of grid is a stabilizing frame upon which counter-point is played. It is elemental theme and supporting structure. Painter and architect are forced to recognize the ordering principle of the intersections of grid. Objects relate in various ways to its dictatorial insistence. They can be outside of it, within it, on top of it, below it — unlimited variance and possibility are inherent about it.

In *Gris' Guitar, Bottle and Glasses*, the use of grid is most pronounced. Two major systems of gridding are incorporated; one at right angles upon the picture plane, the other at 45 degrees. The meshing of the two grids produces innumerable combinations of figure readings. There also is implied a third gridding of 60-30 degrees.

The subtle play of the shaded, shaped, modulated curves and warps creates the necessary concentrations which explode the initial smaller griddings into larger more central squares and diamonds. The smaller, minor spatial griddings have quite simply expanded into larger, major griddings through the use of curved figure imposition and intensity. One is approaching the realm of the infinite. Le Corbusier does not abandon the three dimensionality of architectural space, but he does insist that the observer become involved with the geometric rules of the game. The visual-cerebral mechanism must be generated for total effect to take place. In this respect the intention can be measured as to its validity. The structural frame plays the inquisitor. The Center's column-slab system of construction was stated in all its purity in the *Domino House* drawing of 1914 (Figure 6).

Since that inception, Le Corbusier rarely forgets it and continually is the user. As in most pavillion-loft structures, architectural containment of space is at best problematic. Planes enclose space, lines elaborate; planes emphasize, lines dissolve. The structural bay mentioned is directional, yet square bay readings are possible. Every third column of the lateral spacing completes a square with its opposite number. Le Corbusier wants it both ways. The prime longitudinal reading states first direction, but a more subtle secondary central reading of the square exists. Similar readings found upon the Juan Gris canvases are again discovered in architecture – in a way more diabolical because the idea is running loose in a three dimensional field.

The shape of the structural columns is round, indicating a centrifugal force and multi-directional whirl. In section the columns are at times caught by the floor slabs, at other times they by-pass the slabs and rise uninterrupted through two stories. A piston-plunger; compression-expansion of column lines is effected. Not only are the column lengths modulated, so are their diameters; if the observer takes the same 360 degree course about the columns, he will enter the realm of dynamic and static kaleidoscopic relationships. A 90 degree view parallel to the columns proposes an ordered, static system of space except for the before mentioned peripheric interaction. The observer can now begin the trek of the arc with the next stop at a 60 degree point, then a 45 degree, and finally back to 90 degrees. The spatial views between these fixed geometric points and lines are filled with a conglomerate of fluctuating columnar tensions. First, when one looks into the kaleidoscope, he sees an ordered system. The box is then shaken, the elements move into dynamic relationships and upon deceleration are fixed into a new order. After each shake new spatial configurations take place, the added gifts are the outside walls, bellow-like, compressing and expanding the linear formulation. Still, through this labyrinth one is always conscious of the centralizing aspect of the scheme.

It is hard to believe that anyone could have conceived all these levels of spatial consciousness. It is even harder to believe that they were not so conceived. The above has attempted to explain the technical feats in space accomplished by one of the masters of geometric figures. In a way, Le Corbusier has not been able to detach himself from the Cubist tradition; more cannot be expected from one man's vision. Our heritage is shown and our future can only be anticipated. The technical competence and accurate finish needed to strengthen the

FIGURE 2

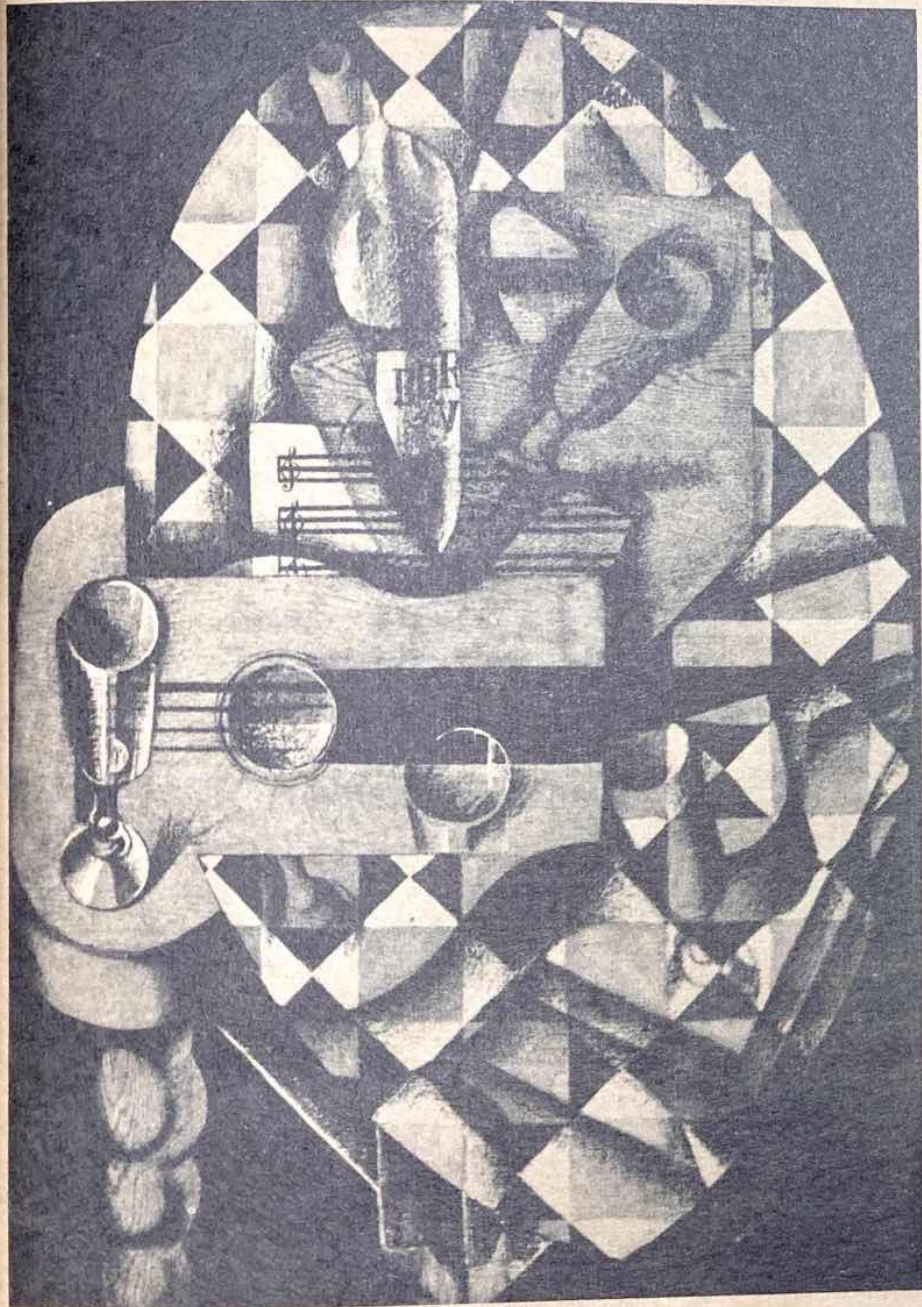


FIGURE 3

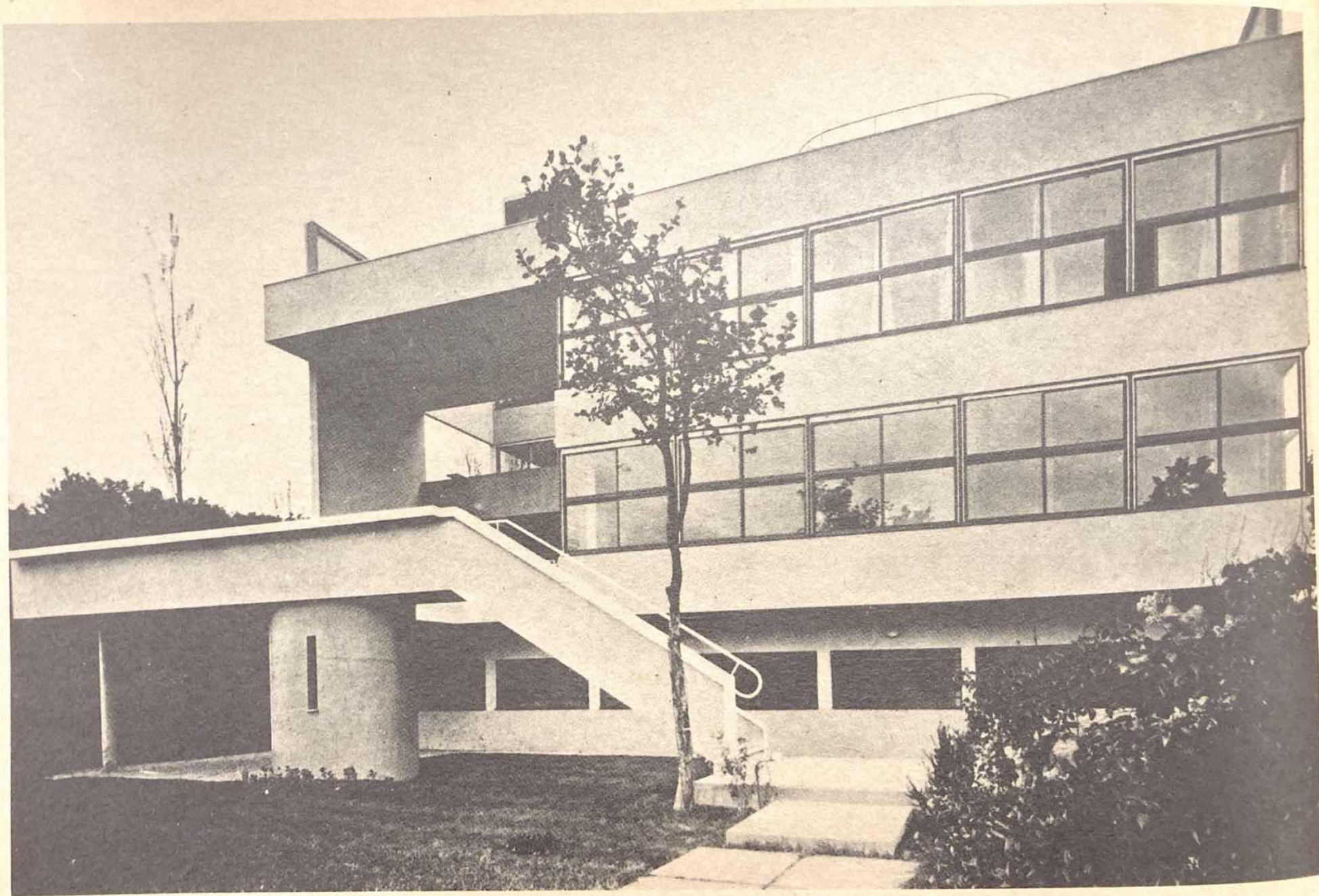


FIGURE 4

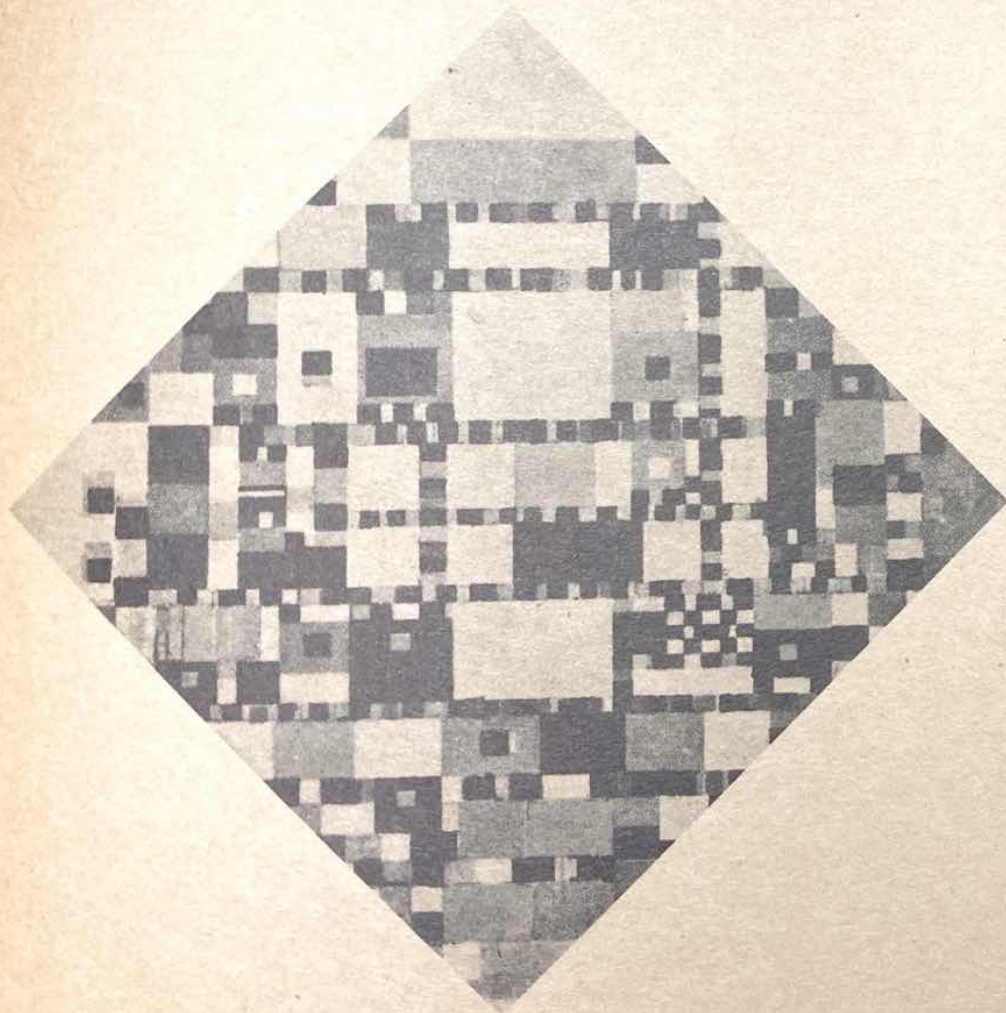


FIGURE 6

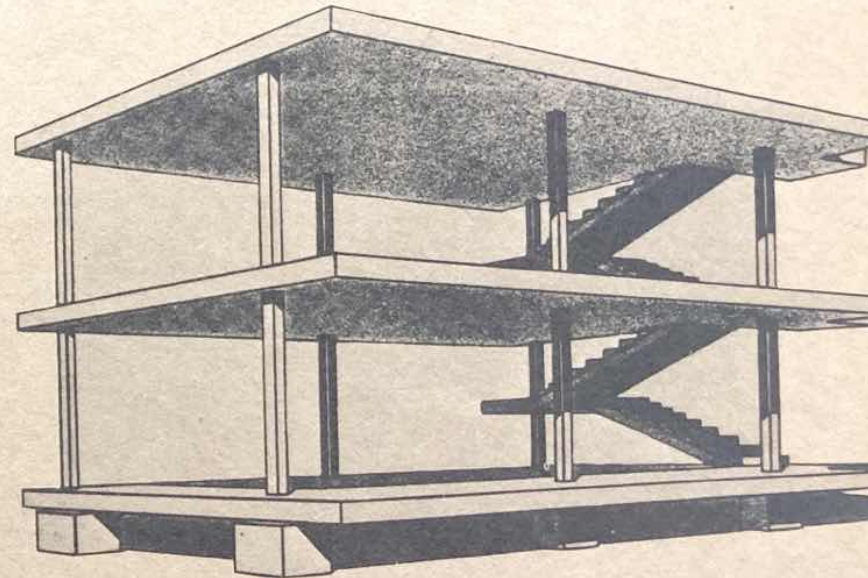


FIGURE 5



theoretical arguments are impeccable. The ease in which one floats through the building is like being on a magic carpet. It makes all things possible. Le Corbusier's solution to clear, defined central circulation is classical.

Unfulfilled promises of past drawings haunt the Center's halls. The vast spaces of the Palace of the Soviets (1931) and the grand stair of the Rio de Janeiro ministry project (1936) are unveiled in a more modest way. The decorative use of color will only sadden the purest of color structure. One can feel secure that all the other promises have been kept.

Of course the old dogmatic arguments between Van Doesburg and Mondrian are again unearthed with the erection of the Center. One imagines Van Doesburg would have been excited and elated were he to be here, and perhaps Mondrian would be interested, impressed, and skeptical. The very placement of the diagonal on the canvas caused the break-up of the two De Stijlists. Mondrian's answer to the diagonal was delivered with tipping the whole field at 45 degrees but insisting on the maintenance of right-angle relationships. This brings up one of the strange feelings of uneasiness upon being lured into the Center. The sense of being twisted and torqued upon the rack of Architecture is a new one. The tension-compression, the push-pull may have therapeutic value to the docile; the question remains, at what point do the harmonic fluctuations crack causing dissolution and failure to the spatial organism?

Mondrian's concern for the spatial-architectural dilemma was prophetic. 'Painting can be a purely abstract expression. In painting reality is established with the limited space of the canvas which can be completely determined by planes. In sculpture and in architecture, the work is a composition of volumes. Volumes have a naturalistic expression. Seen, however, as a multitude of planes, sculpture and architecture can be an abstract manifestation. Moving around or within a rectangular building or object, it can be seen as two-dimensional, for our time abandons the static vision of the past. By moving around, the impression of a two-dimensional aspect is directly followed by that of another two-dimensional aspect. The expression of the structure, form, and color of the planes can have a continuous mutual relationship which produces a true image of the whole. This fact shows the intrinsic unity of painting, sculpture, and architecture.'

The conception of a mobile viewpoint appeared first in early Cubism. Already in that tendency, the need for a truer and more concrete expression was felt. But this Cubism intended to express volume. Intrinsically it remained naturalistic. Abstract Art attempts to destroy the corporeal expression of volume; to be a reflection of the universal aspect of reality.' ††

Skepticism can cause the martyrdom of an idea; inquiry can cause its liberation. Civilized memory may be preferable to barbaric sensibility. If the ordinary mortal of architectural endeavors had to conceive works in such a complex manner there would probably be fewer buildings — on the other hand perhaps better ones would be imagined.

It appears that the revolutionary tribunal has relaxed its stringent laws as regards the encyclicals of purism, in favor of a more tolerant acceptance of spatial views. When the laws are not enforced, neither are the forms. Perfect works not only become impossible, they become undesirable. When the pursuit of the ideal is cut off, so is the bloodstream of an organic unity — where flow the genes of codified space. When everything is permitted, limits are in jeopardy — objects then enter the realm of the celestial float.

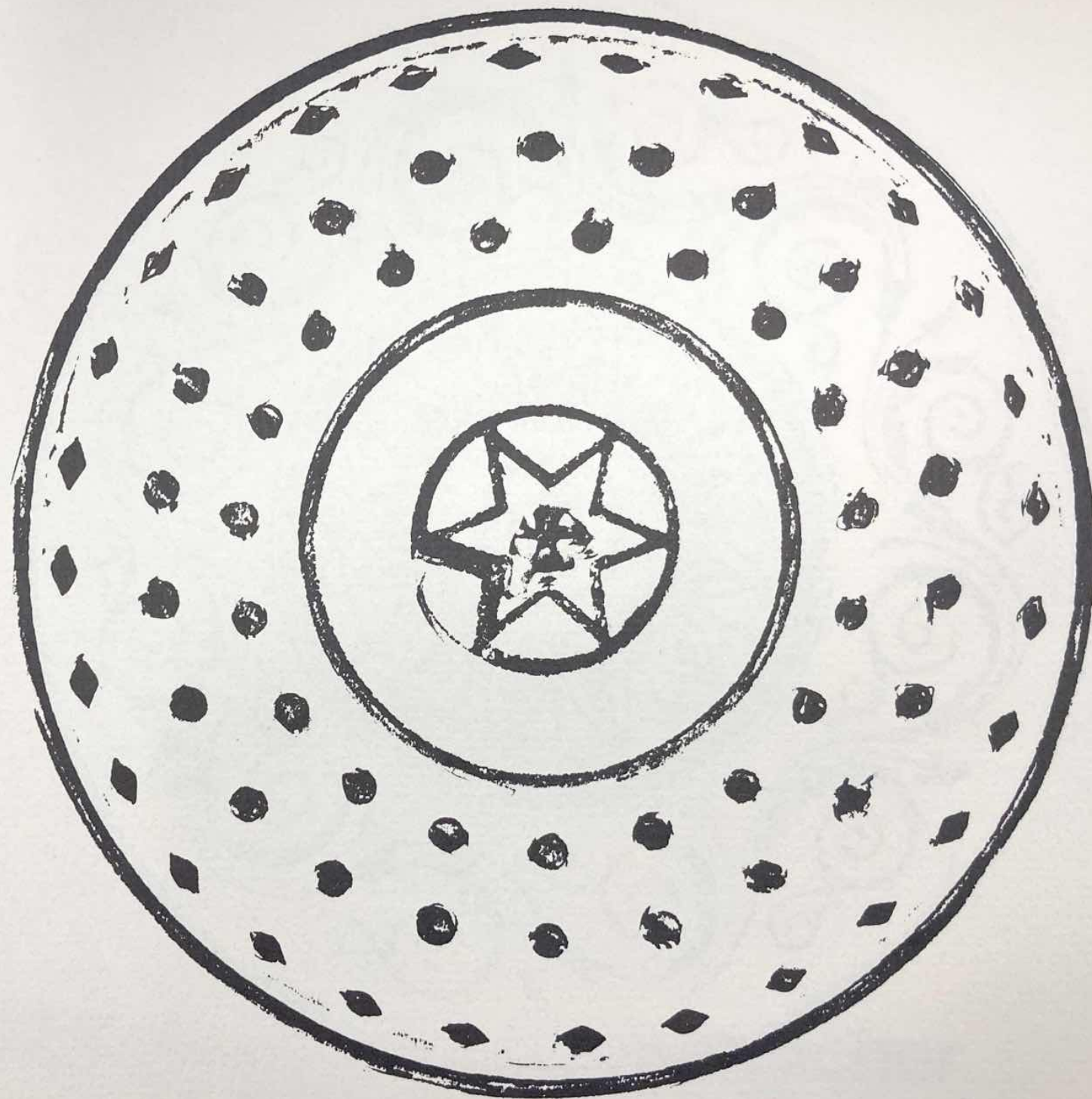
The joy of the remembrance of things past. Fernand Leger returned to painting figures incorporating all the principles of the new spatial discoveries. Braque returned to flowers. Le Corbusier, in a similar way, returns to some of his early triumphs with a more poignant commitment to expanding space. If the Harvard Visual Arts Center had arrived prior to *Villa Garches*, all the armchair historians could rest unmoved, for 'was this not the natural order of events?'. The fact that it post-dates *Garches* by some 30 years can only prove the quirks of time. Whereas *Garches* heralded the promise of things to come, the Center postpones them. Whereas *Garches* appealed to the proper elite, the Harvard Center appeals to the improper common; it is, to put it bluntly, 'as you like it'. Some won't, some will.

†† A New Realism — April, 1943



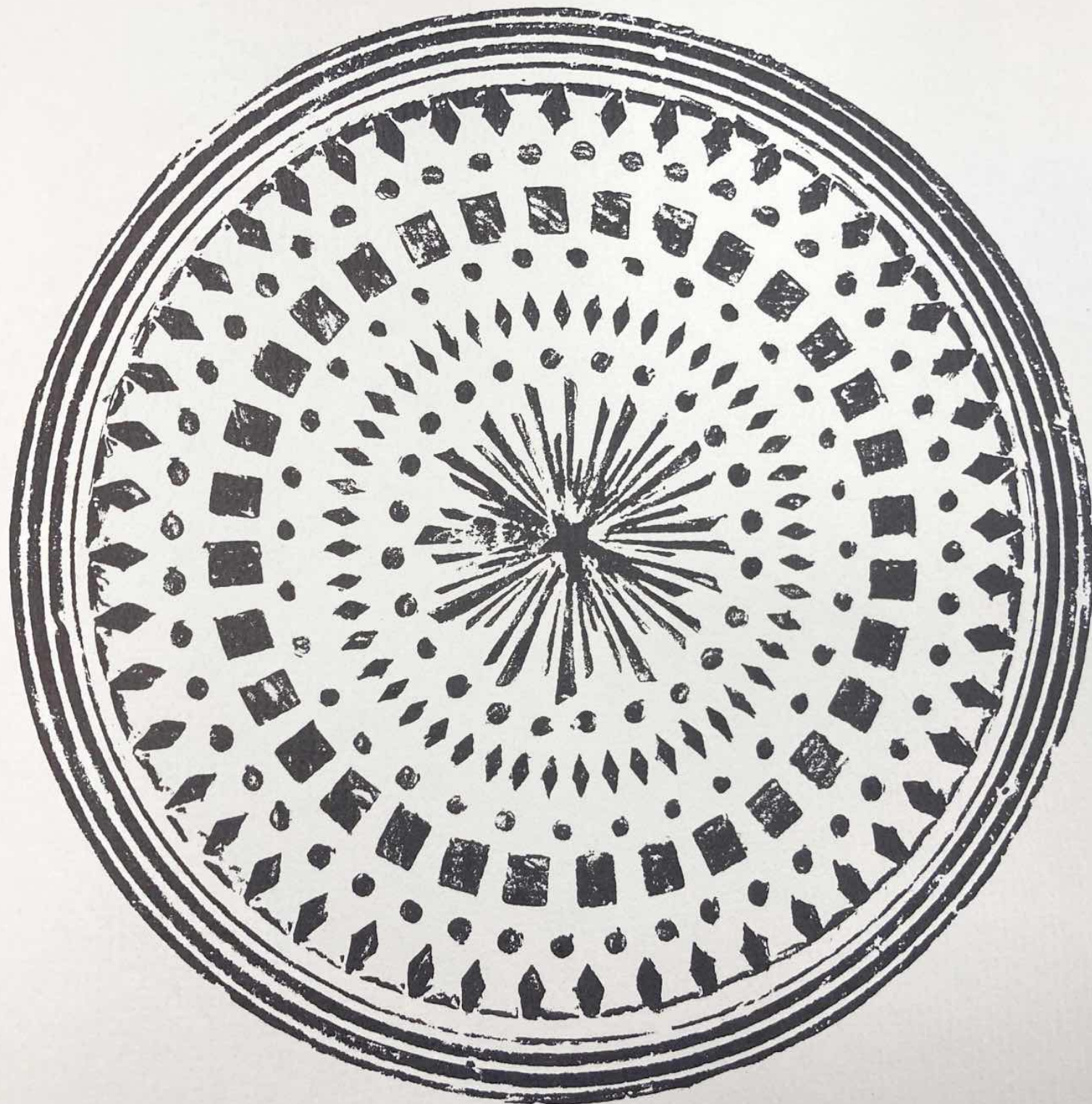
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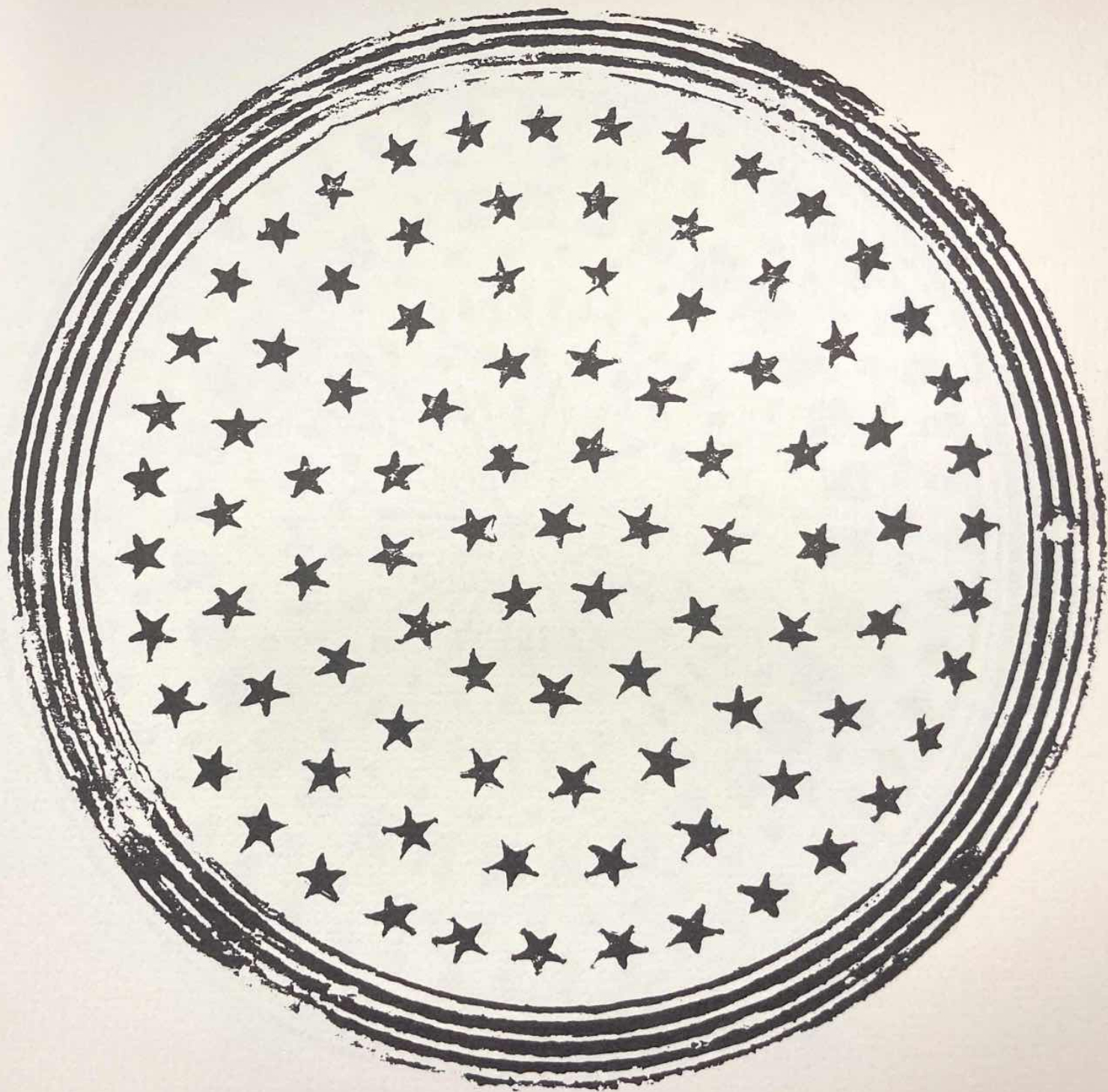






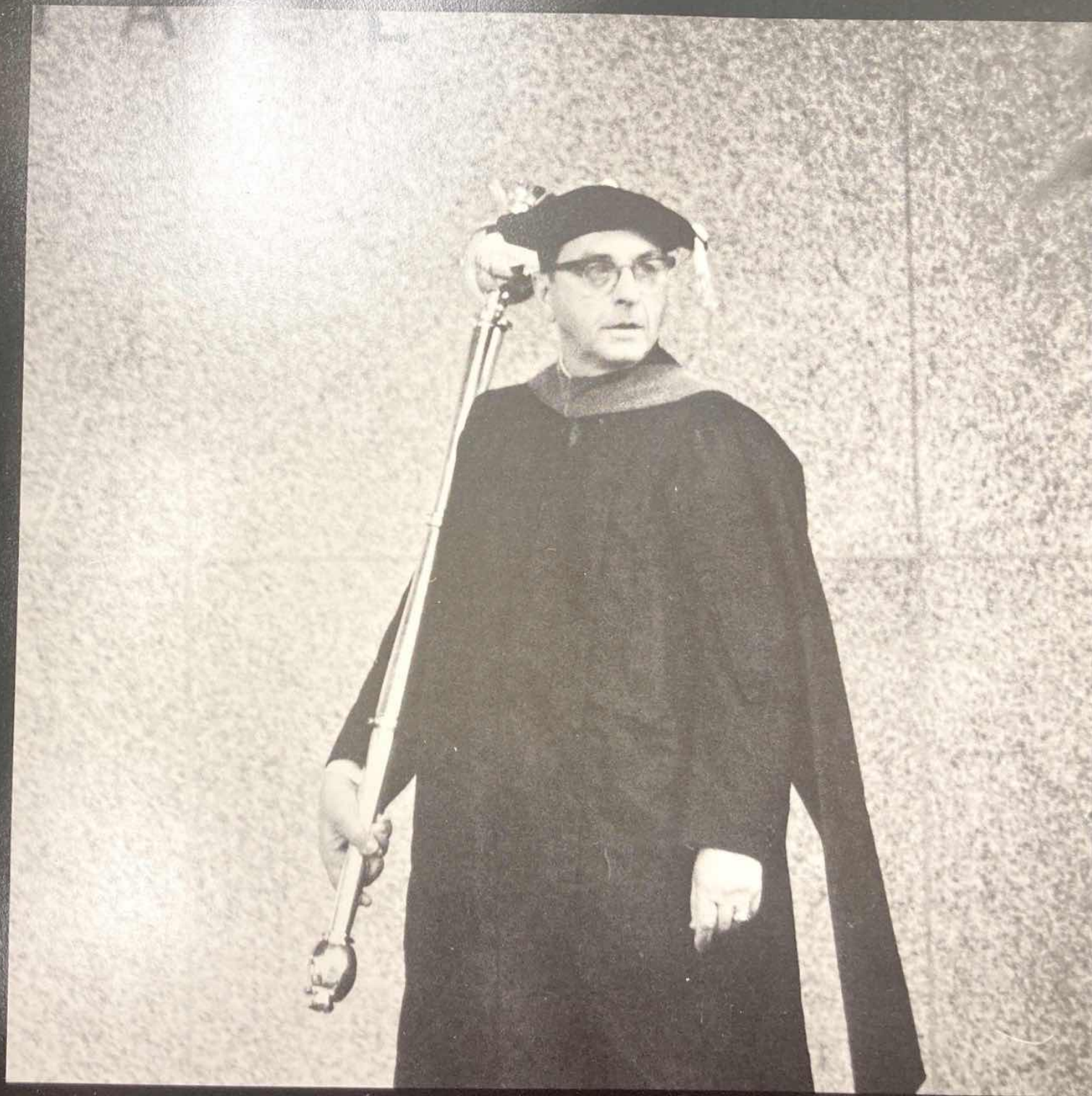




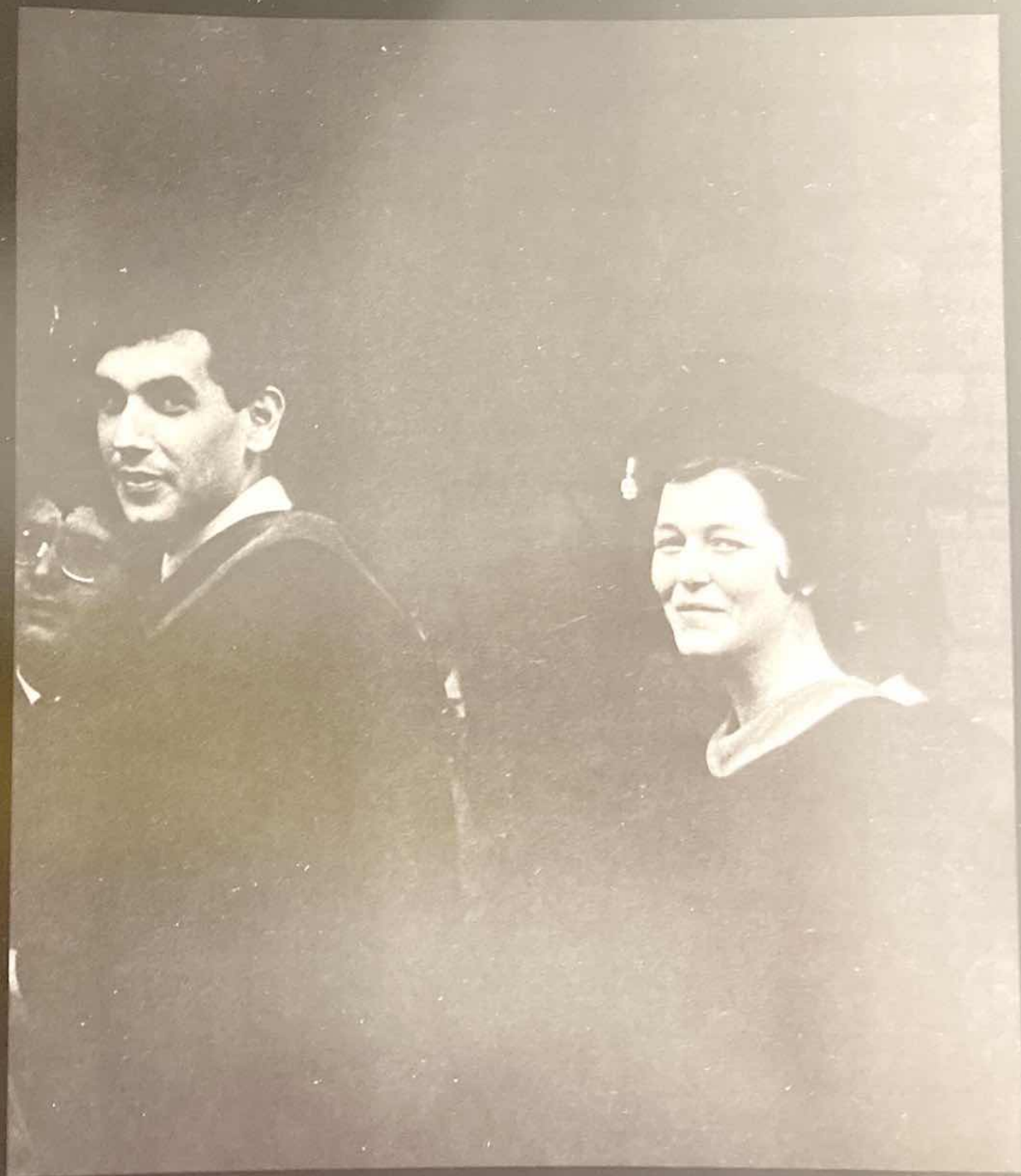










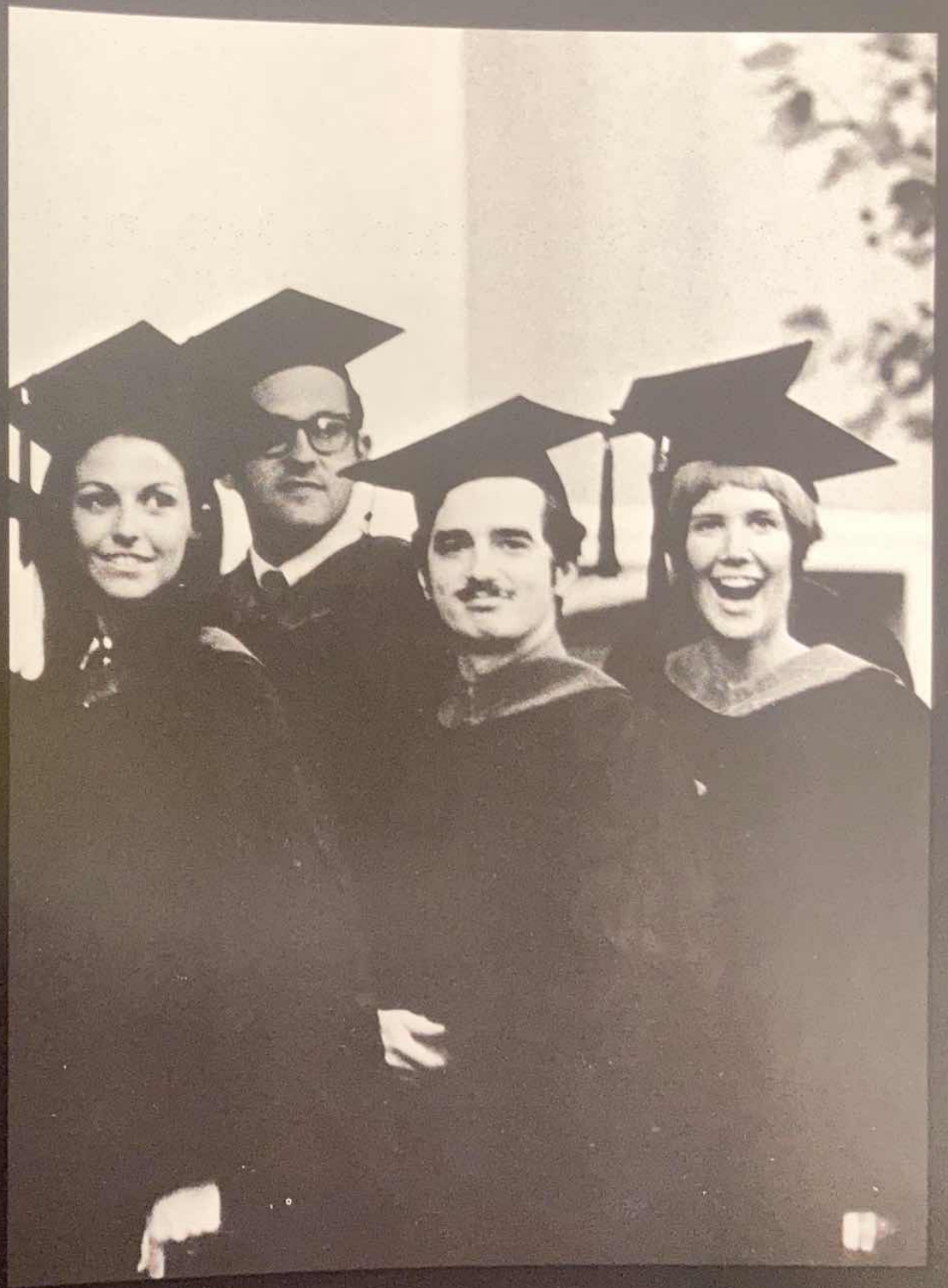


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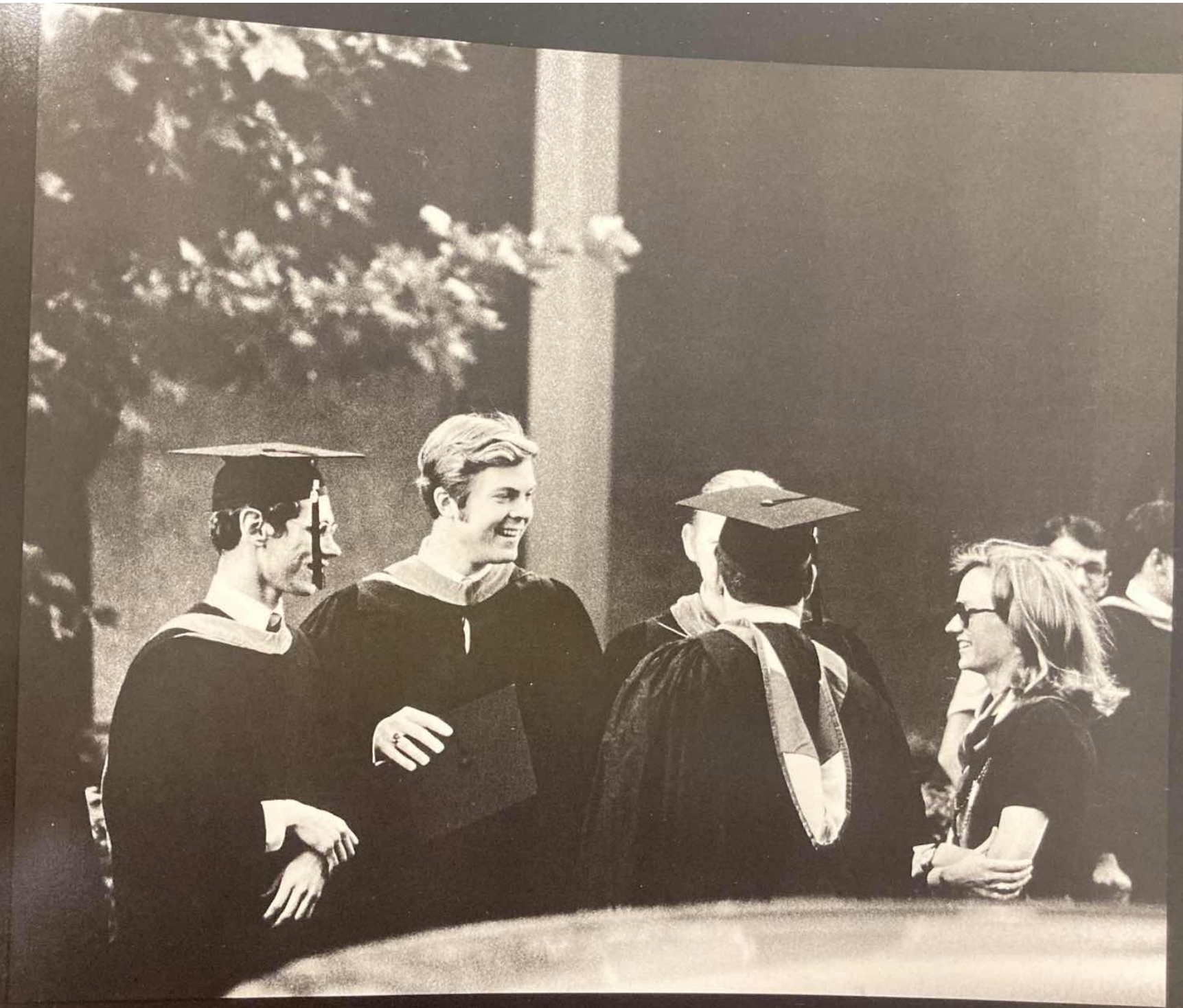
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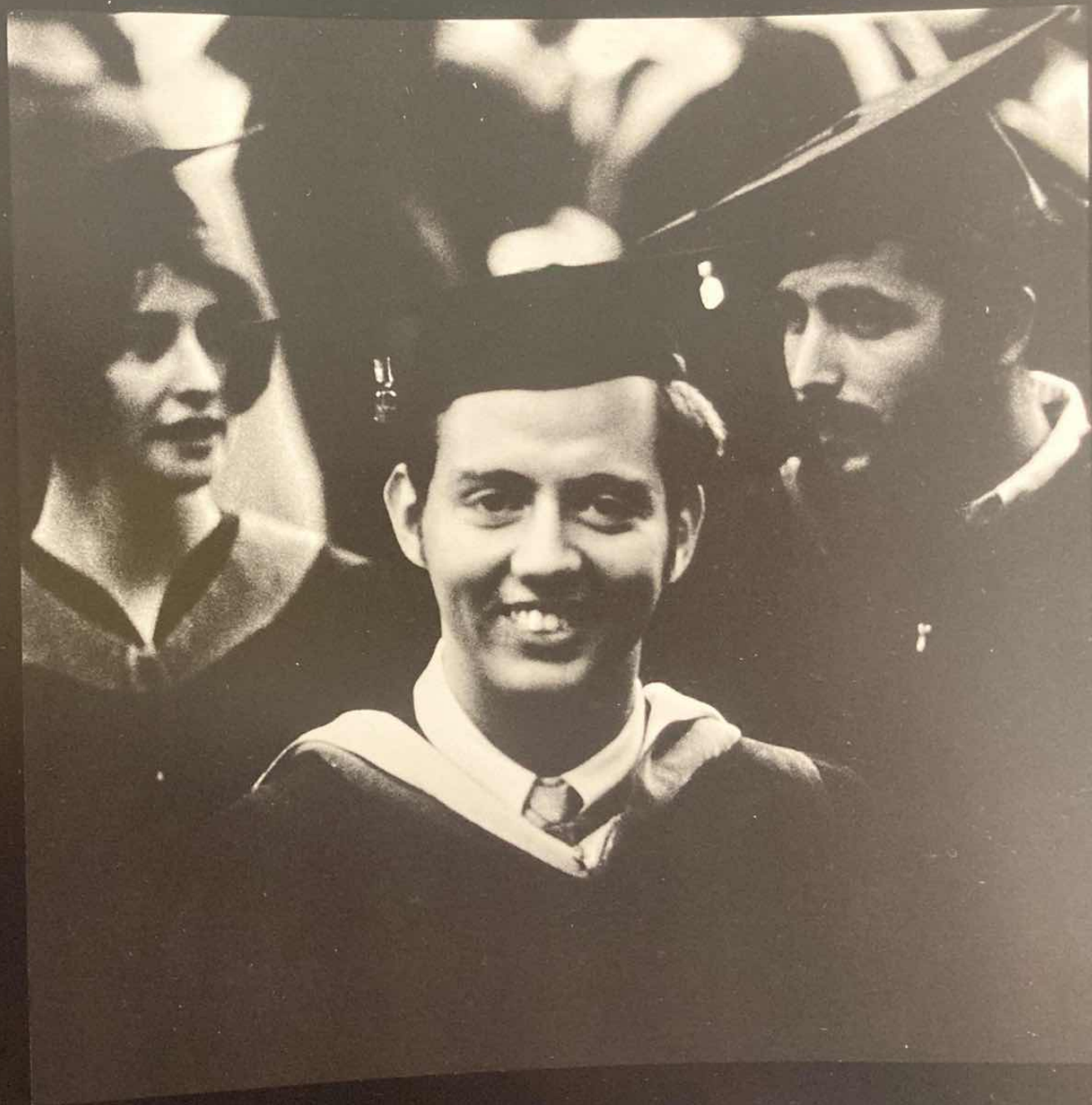
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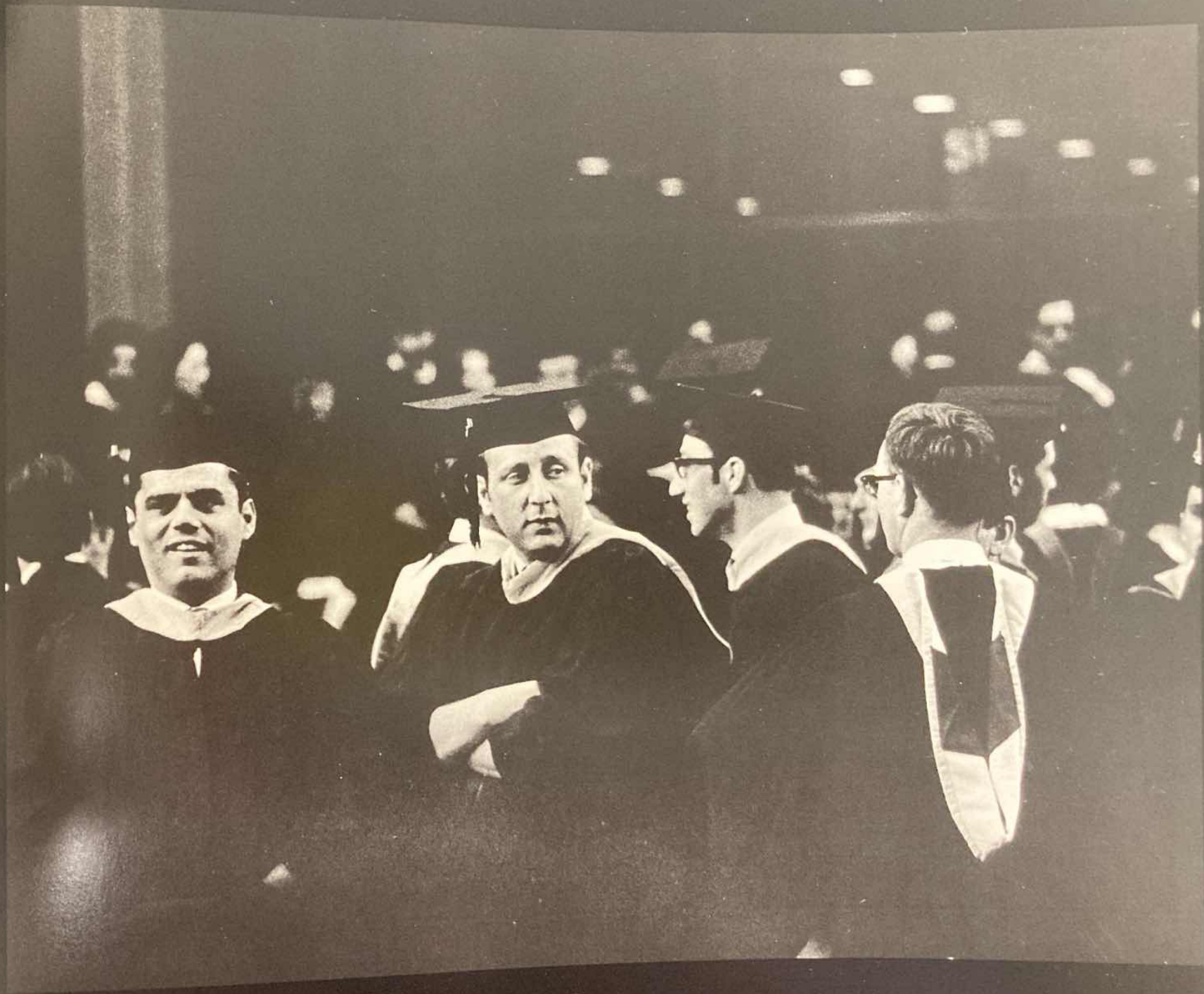
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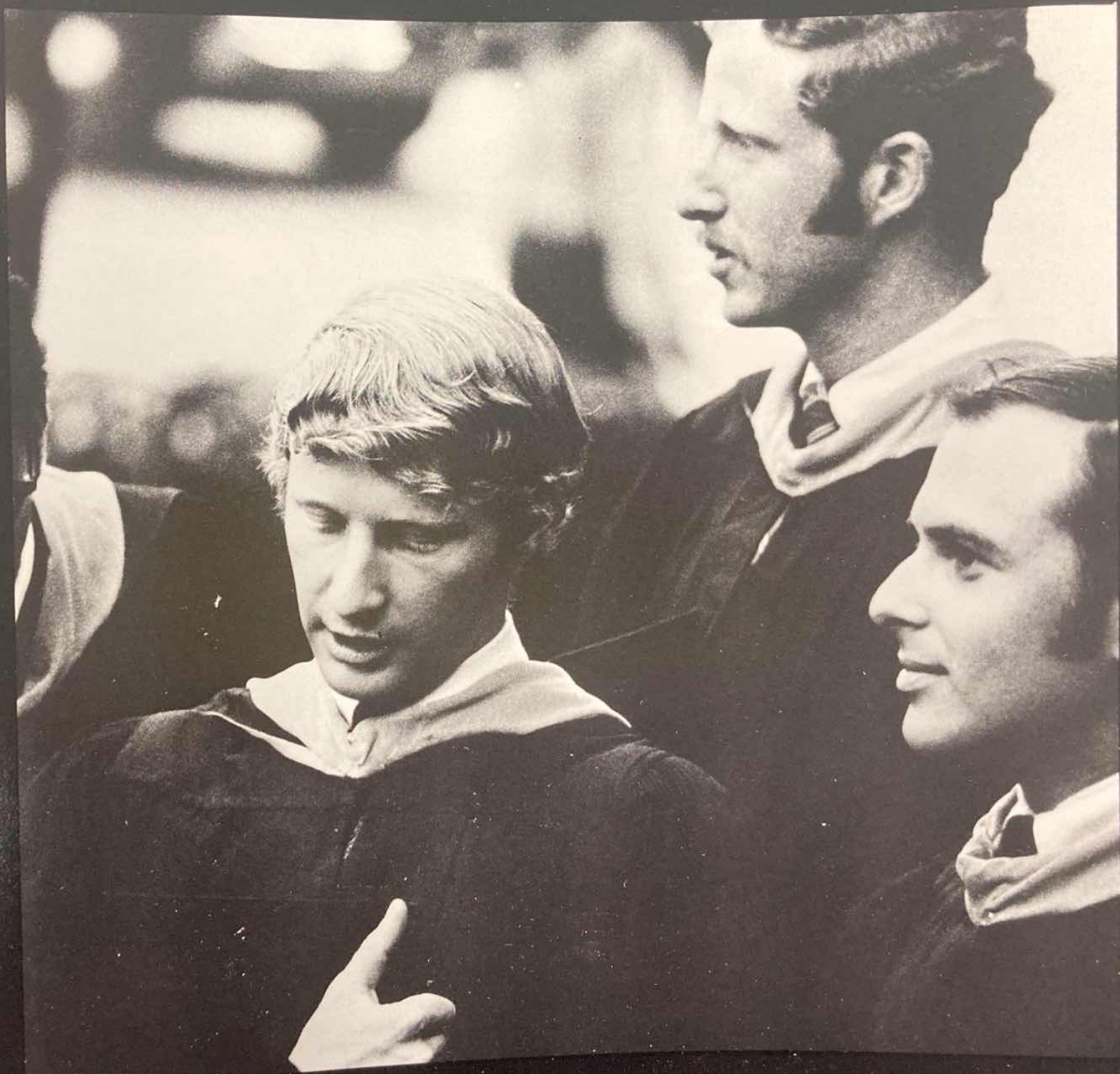
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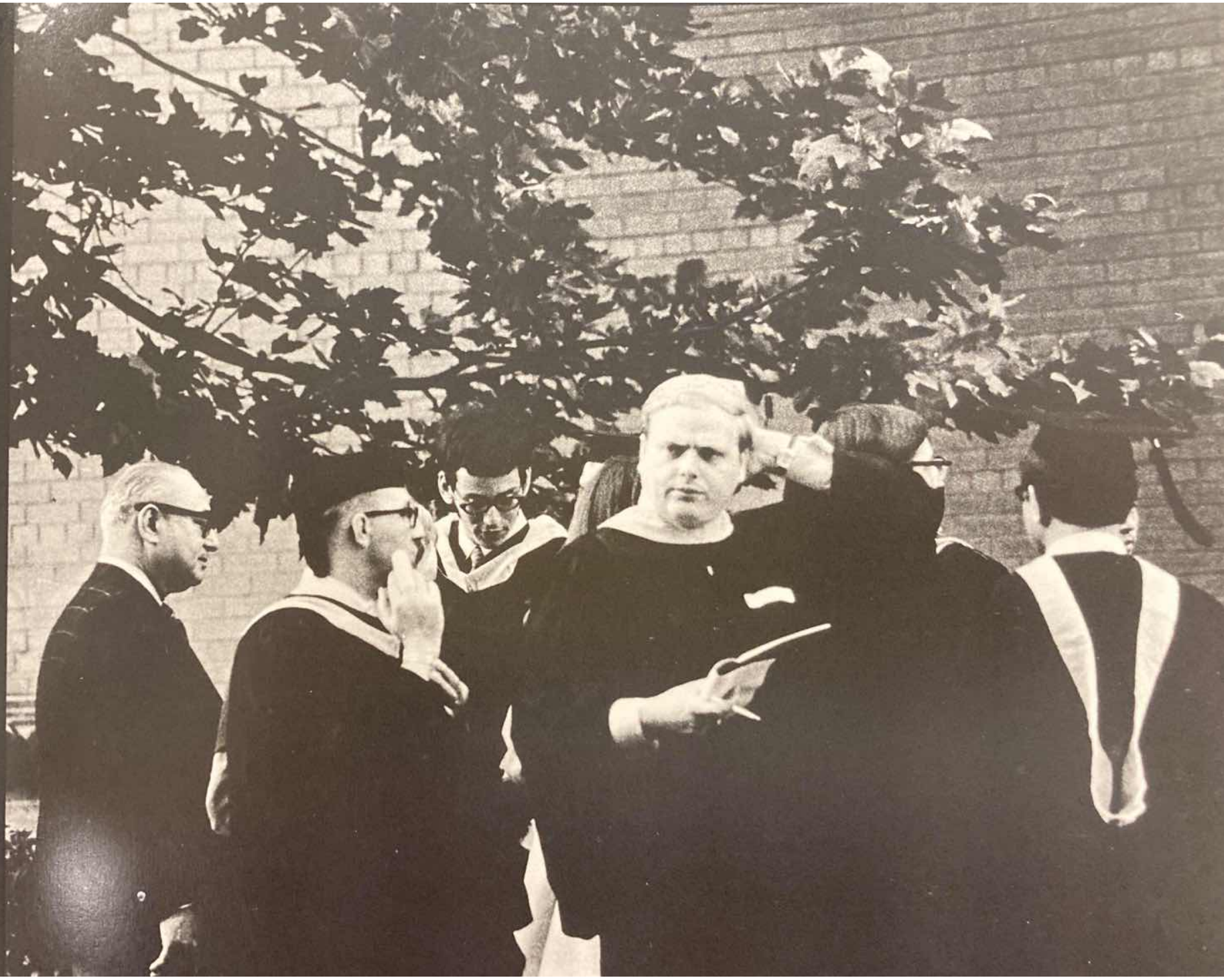
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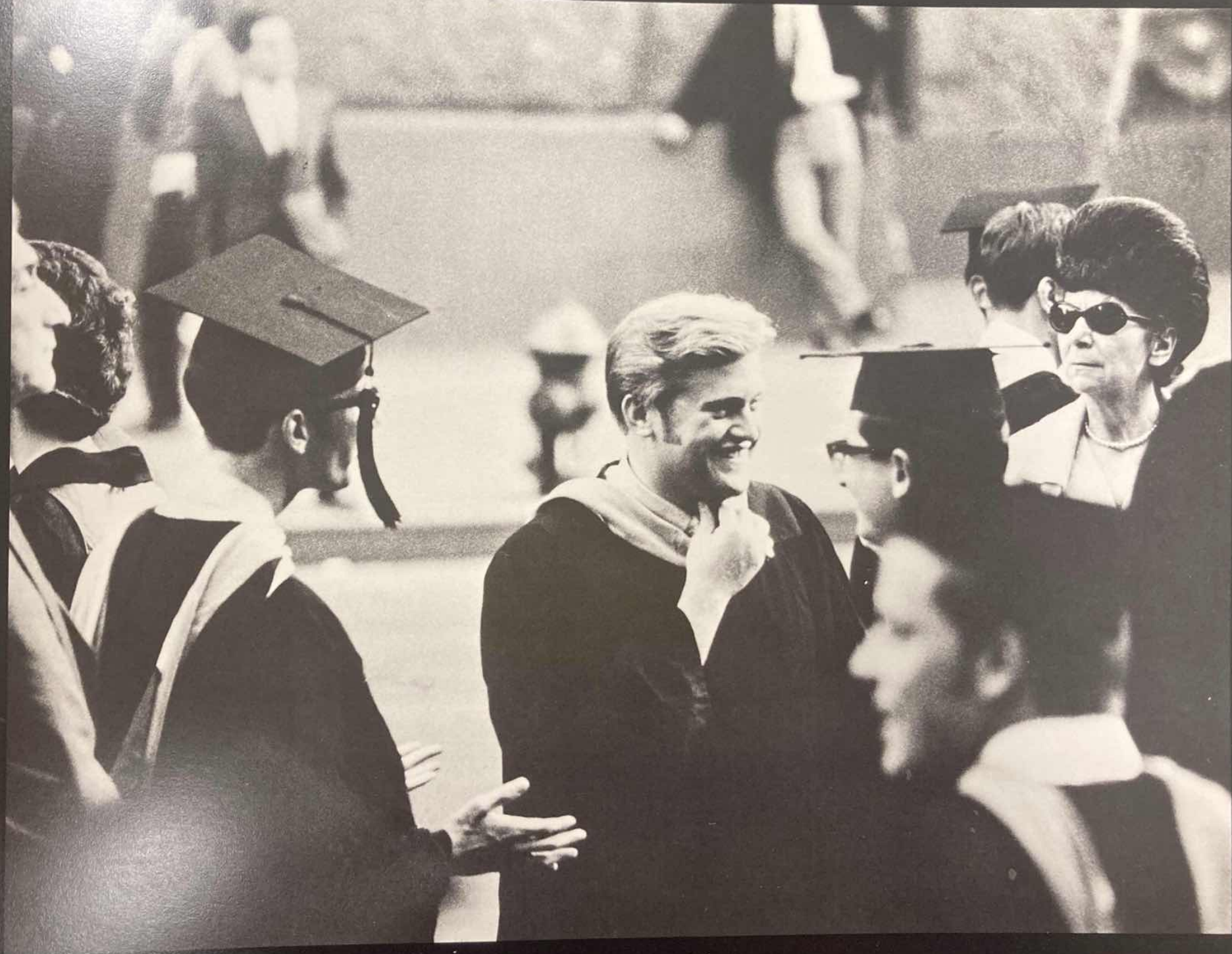


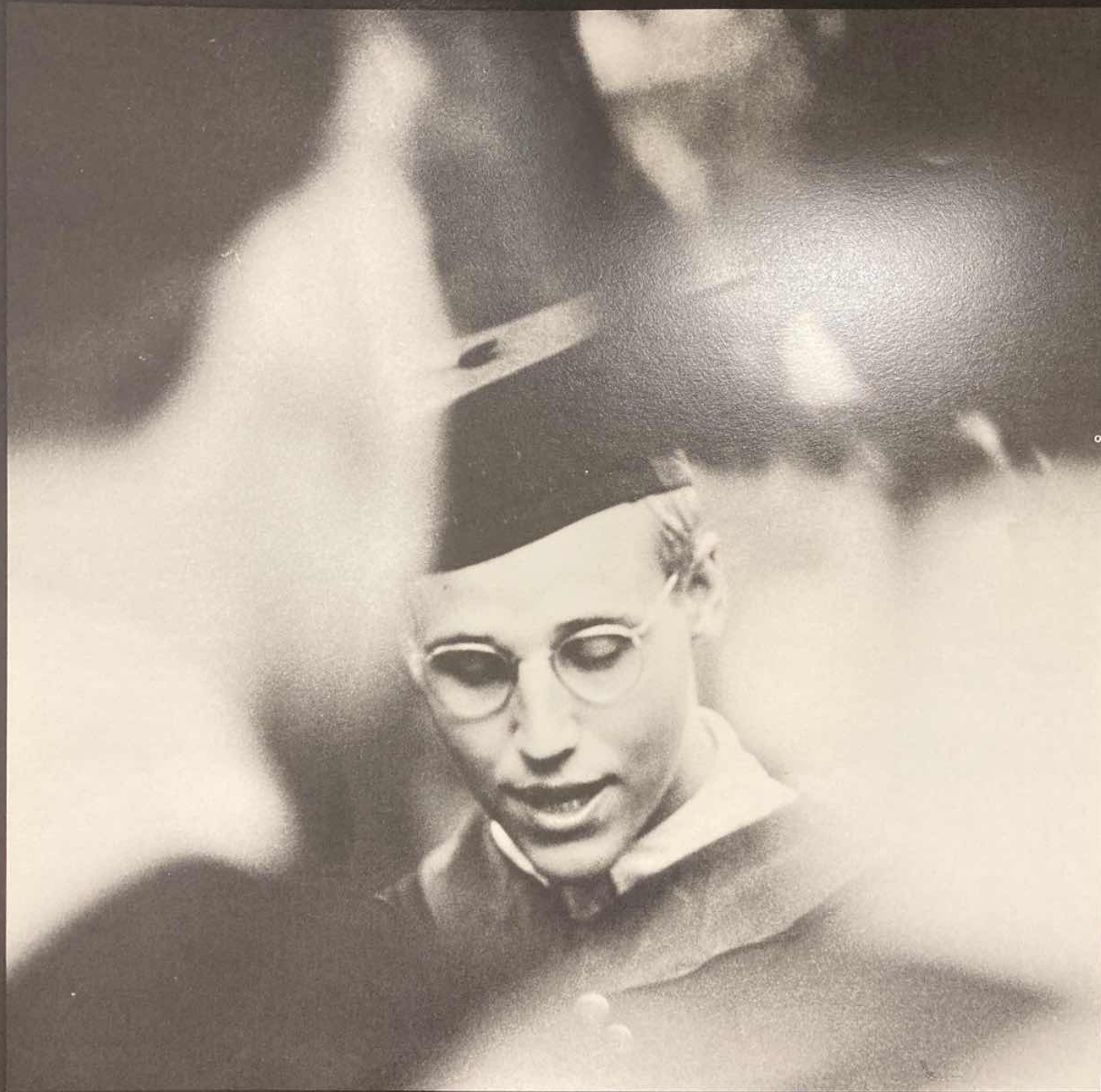
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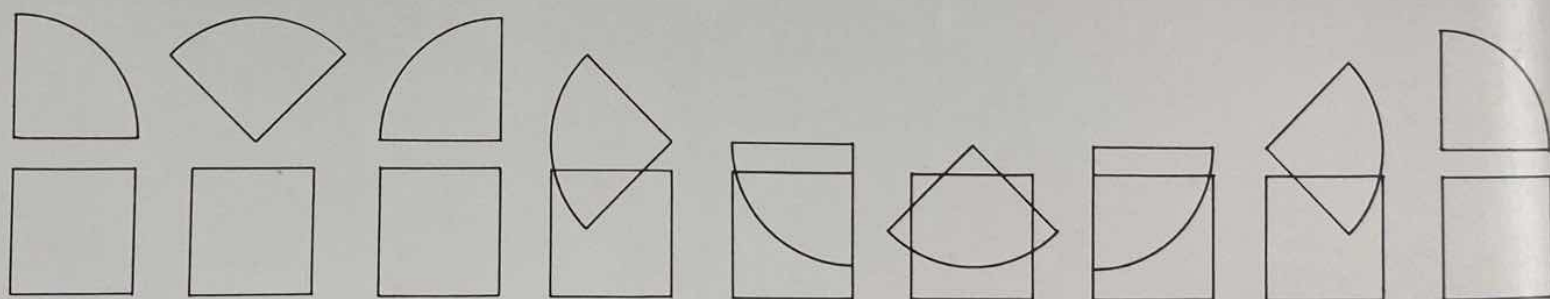


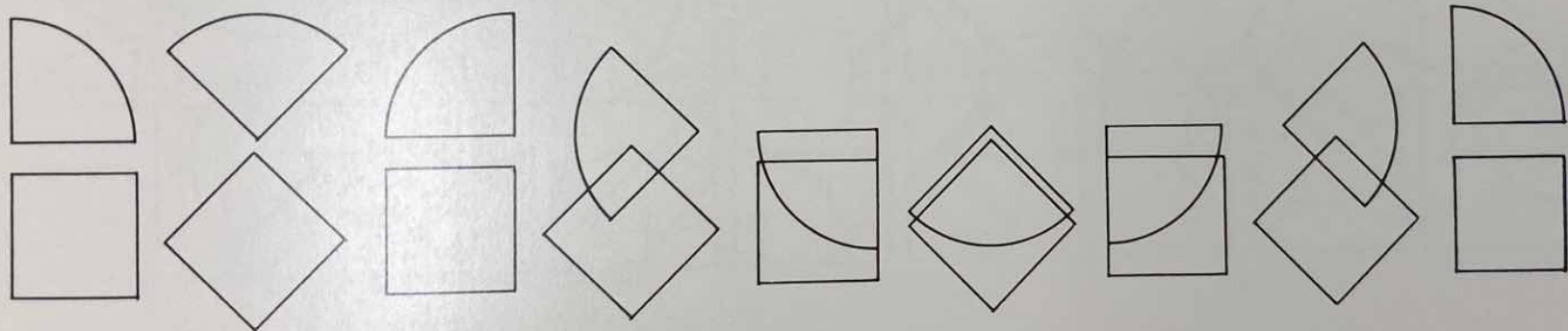


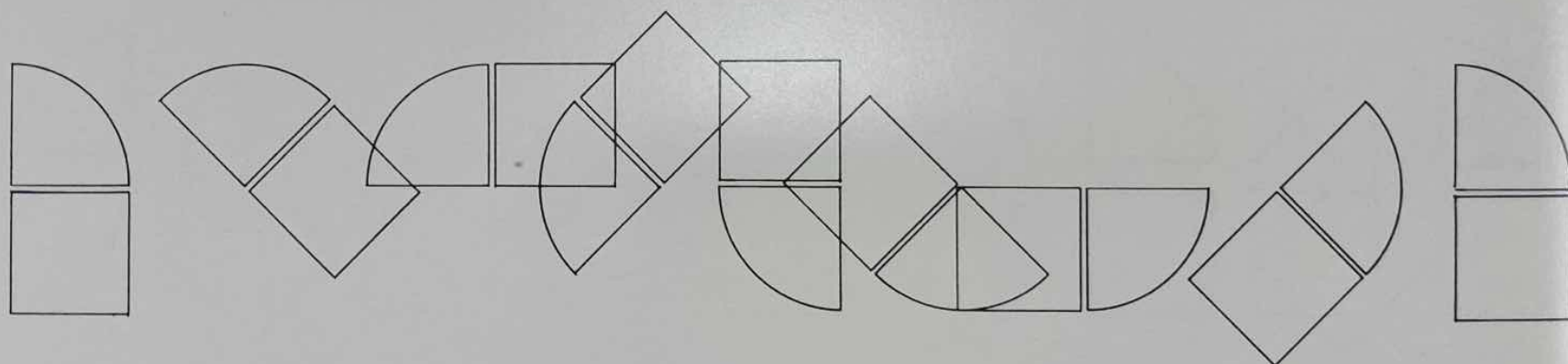


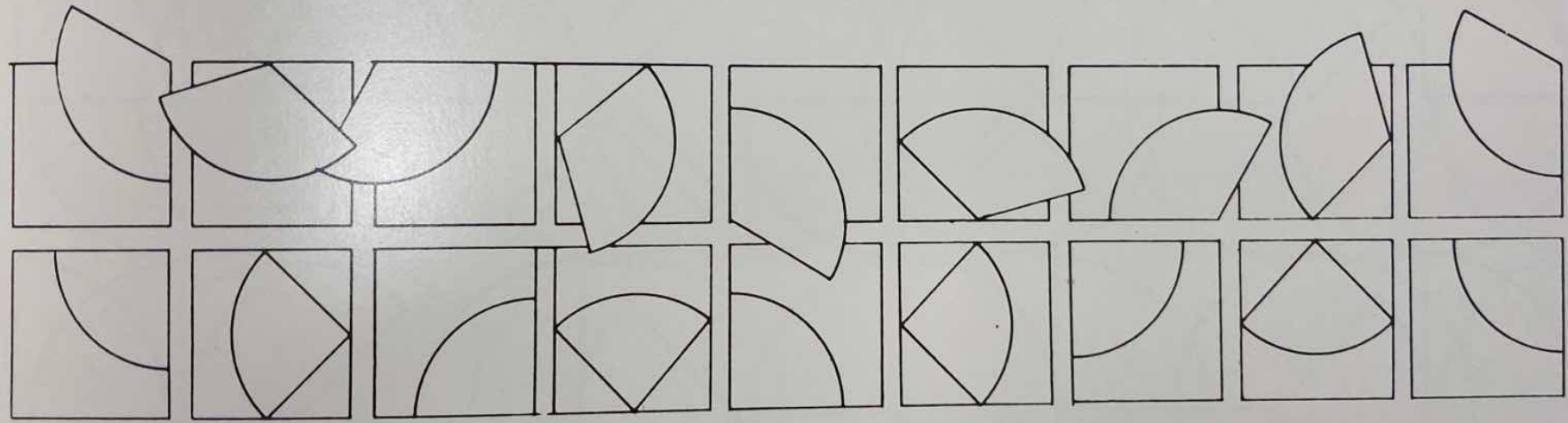
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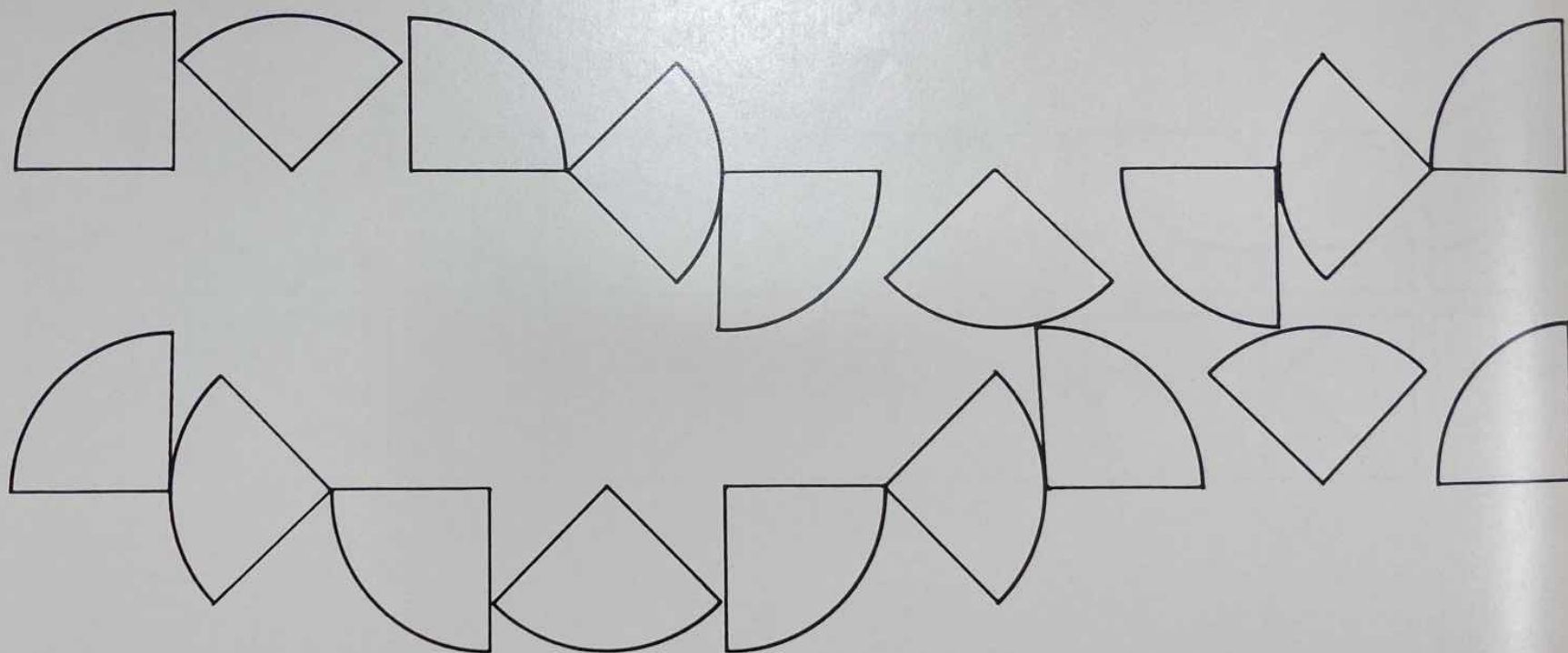
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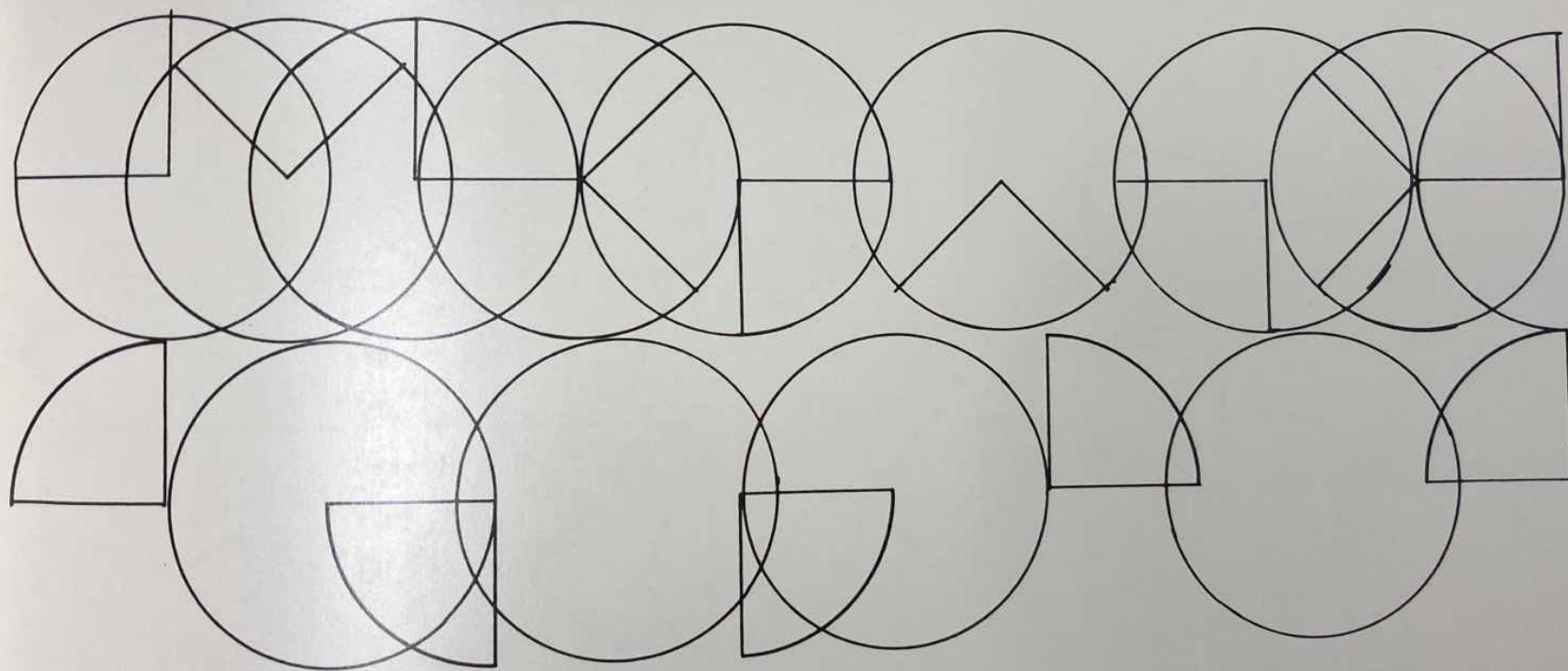


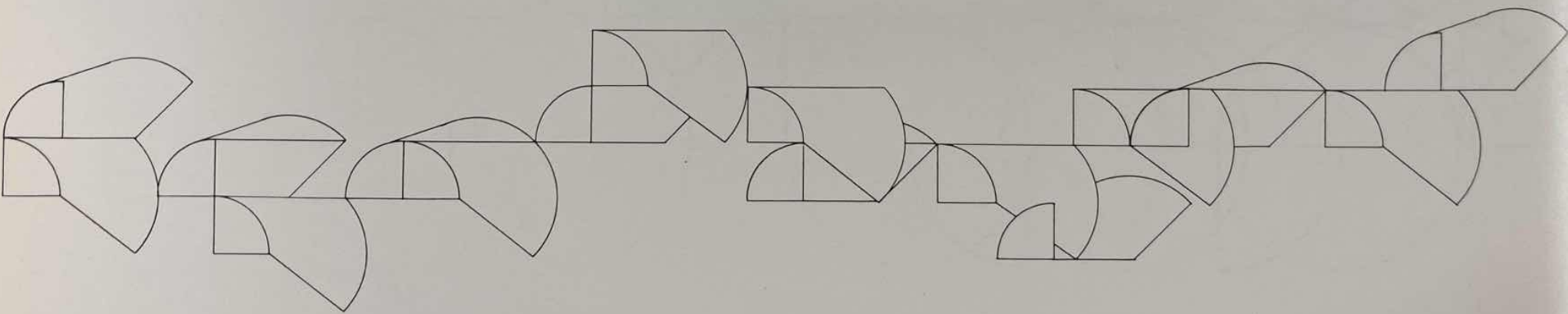


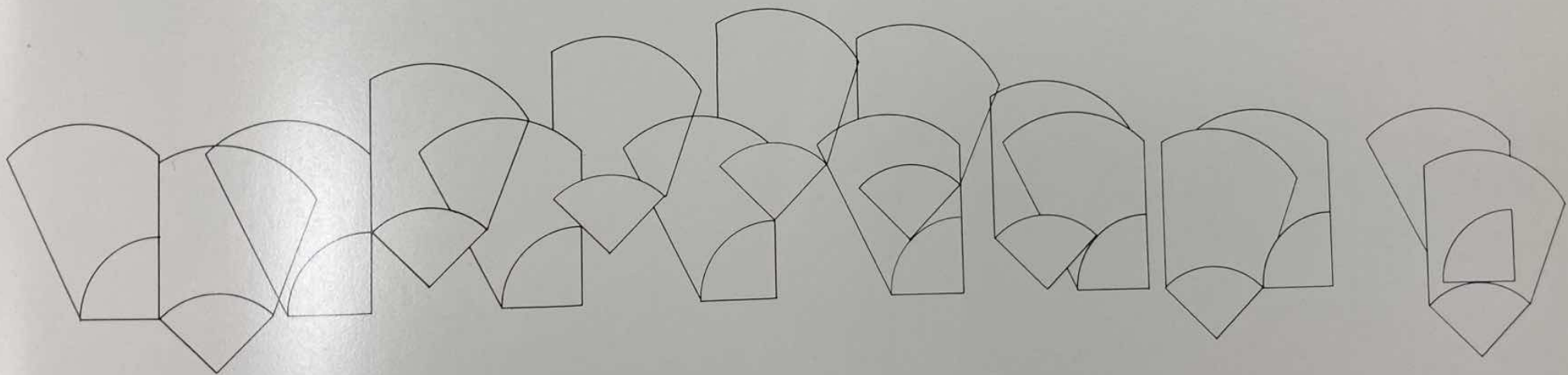


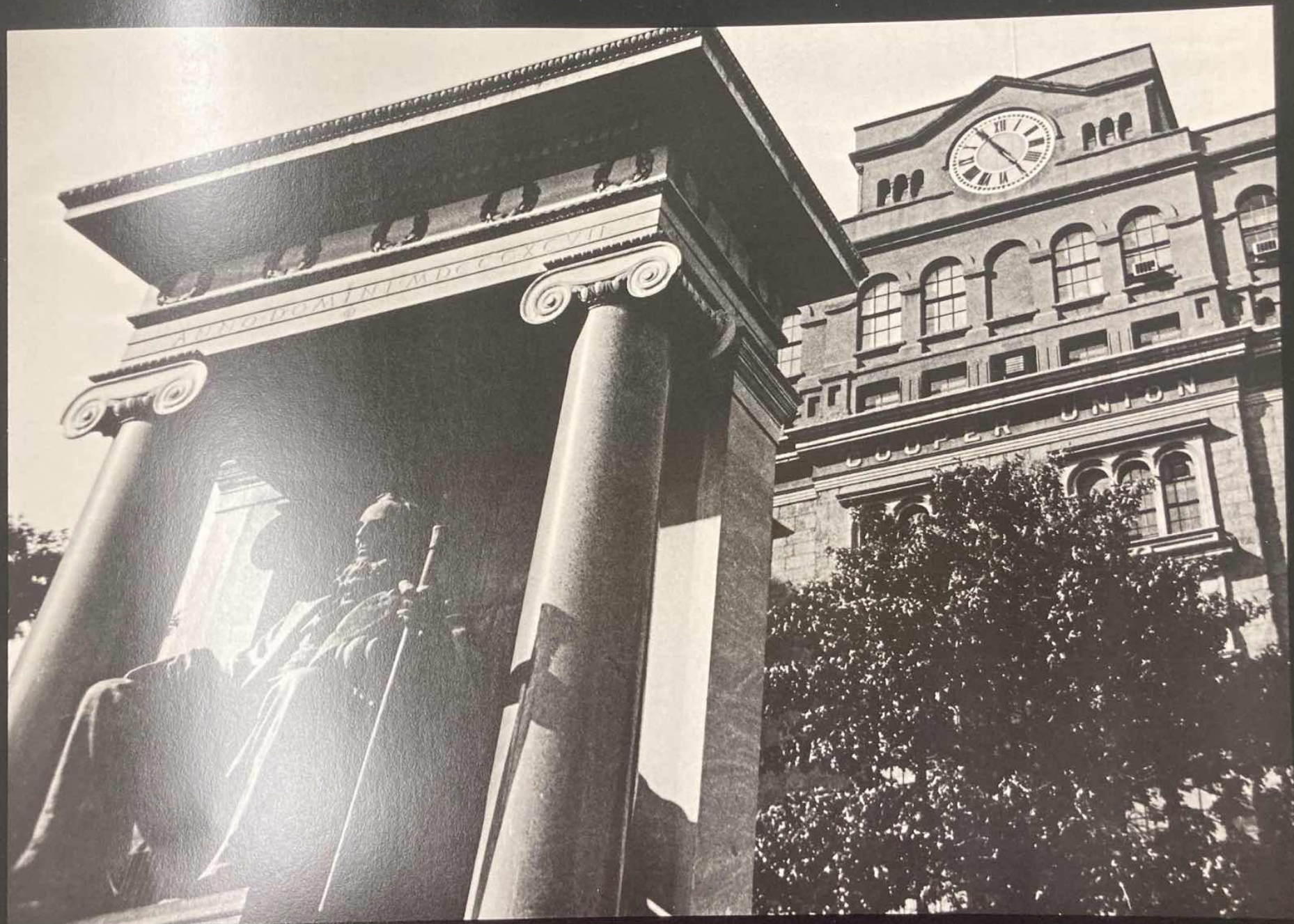


















CHARLES

*Son of Alfred &
Amanda Morris*

BORN

March 8, 1853.

DIED

April 26, 1878.

